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THE CATTLE LICE OF GREAT BRITAIN

PART II. LICE POPULATIONS

BY

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THE CATTLE LICE OF GREAT BRITAIN

PART II. LICE POPULATIONS

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(With 4 Figures in the Text)

CONTENTS

1. Introduction

A previous paper, Craufurd-Benson (1941) gave details of the biology of the cattle lice, with special reference to *Haematopinus eurysternus*. The present paper deals with the seasonal variations of lice populations, and their distribution on the host at different times of the year. The latter is referred to as the regional distribution of lice.

The information has been obtained from two main sources, (*a*) by monthly examinations of cattle at this Research Station, and (*b*) by the distribution of a questionnaire to farmers.

2. Methods

The seasonal and regional distributions of the lice populations were assessed by a monthly examination of ten dairy Shorthorn heifers. In January 1938, the 12 months old heifers had been running in the field since the previous May. The *Bovicola bovis* and *Linognathus vituli* infestations were natural, but the

Haematopinus eurysternus infestations were started artificially in December 1937. At the end of 1938 the ten heifers under examination were replaced by ten 12 months old dairy Shorthorn heifers. In December 1938, the new heifers were found to have considerable infestations of *H. eurysternus*, but had to be artificially infected with *B. bovis*.

The various surface areas of a heifer were defined, and the populations of lice in each area assessed by eye, as the habit of lice to collect in groups rendered it undesirable to adopt a precise method of counting. By experience it became possible to assess the density of any population in one of five categories, and assess the total infestations on a point system, namely, (*a*) very light infestation (1 point), (*b*) light infestation (2 points), (*c*) moderate infestation (3 points), (*d*) heavy infestation (4 points), and (*e*) very heavy infestation (5 points). The presence and number of eggs observed were not used as an indication of the severity of lice, as the egg shells of *H. eurysternus* will remain attached to the hairs for a considerable time after the eggs have hatched, and the apparently unhatched eggs may actually be sterile eggs of considerable age.

The limits of the surface areas of the cow were fixed arbitrarily and the names given to each area are self-explanatory.

3. Seasonal variations

The total lice populations of the ten heifers for each month of the year are shown in Table 1 and Figs. 1 and 2.

Table 1. *Seasonal variation of lice populations*, 1938 *and* 1939

	Total points for month			
Month	*H. eurysternus*	*B. bovis*	*L. vituli*	*S. capillatus*
1938: January	60	150	29	—
February	70	160	32	—
March	66	186	8	—
April	24	22	4	—
May	19	6	0	—
June	17	4	0	—
July	17	4	0	—
August	21	7	0	—
September	24	9	0	—
October	28	11	0	—
November	35	15	0	—
December	58	20	0	—
1939: January	136	11	—	36
February	144	23	—	34
March	98	20	—	25
April	31	26	—	23
May	11	12	—	8
June	2	7	—	1

The records of the variations of the lice populations of all four species of cattle lice show the same general decrease in the populations in the spring. *H. eurysternus* and *B. bovis* populations both increase at the same time in the autumn, and it is probable, although not observed, that *L. vituli* and *S. capillatus* populations would also increase at this time. This suggests that all

four species of lice are reacting to the same factor or combination of factors which control the population densities.

The farmers' observations of the seasonal incidence of lice in general, are given in Figs. 1 and 2 for comparison, where they show a general agreement.

Several of the infestations of *B. bovis* died out during 1938, so that in Fig. 2 a second graph is given showing the infestation level per infected heifer.

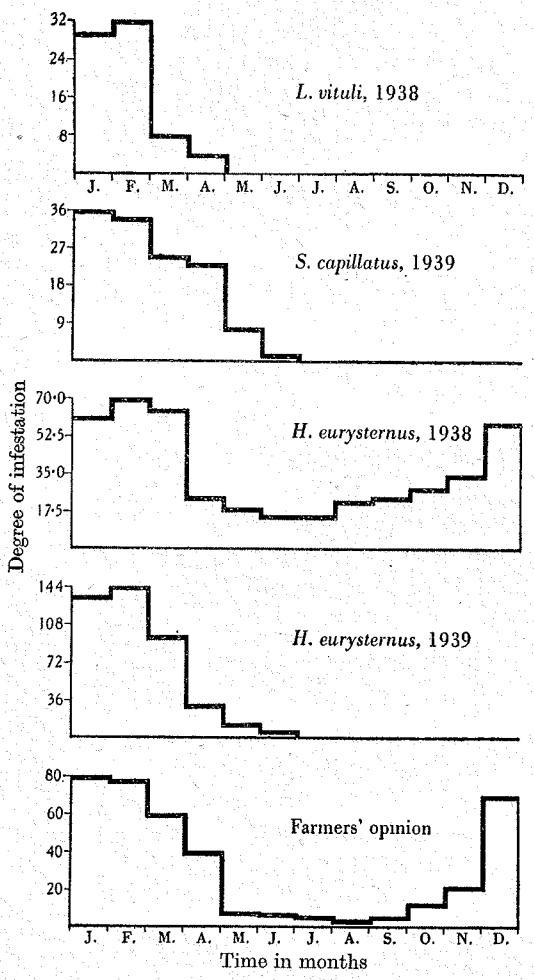

Fig. 1. Seasonal variations of the populations of the sucking lice.

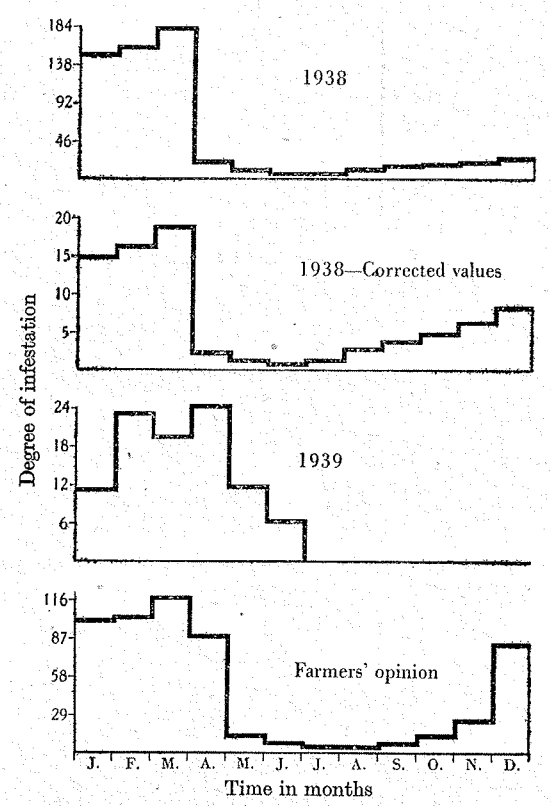

Fig. 2. Seasonal variations of the populations of *B. bovis*.

This gives a more accurate picture of the seasonal increase of the populations in the autumn.

One of the ten heifers in 1938 maintained a high population level of *H. eurysternus* in the summer months. It appears, therefore, that most cattle retain very light infestations in the summer. Some infestations die out altogether, and, in other cases, a high infestation is maintained and the sus-

ceptible animals may be the means of restarting infestations in the following autumn. This last phenomenon has been observed by farmers.

The observations of other workers on the seasonal prevalence of lice can be summarized as follows:

Authority	Seasonal prevalence of lice
Akinschin (1914)	Spring
Cooley & Parker (1916)	In colder months
Imes (1925)	Winter
Lamson (1918)	Winter
Roberts (1938)	Chiefly winter and spring
Shull (1932)	Winter
Underhill (1923)	Commonest towards close of winter months
Walton (1924)	Early spring

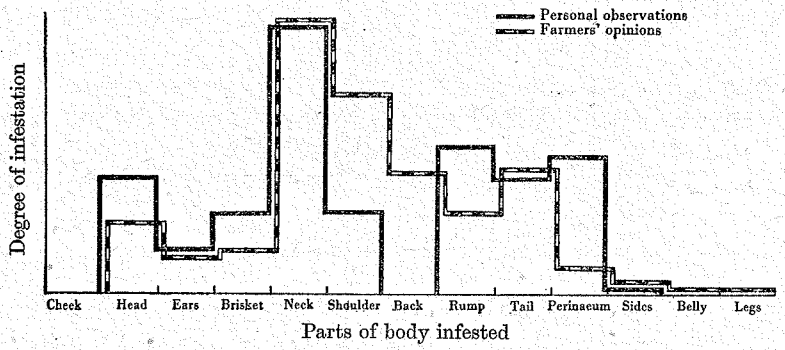

Fig. 3. Typical regional distribution of the sucking lice in the winter.

4. Regional variations on the host

The regional distribution of the lice on the host at different times of the year were assessed at the monthly examinations. In addition, there are eight records of heifers examined at different times of the year, in which every louse of *H. eurysternus* was counted and a chart made of its position on the body, and one count of a *B. bovis* population. The general conclusions from these counts, on sex ratios, etc., have been discussed (Craufurd-Benson, 1941).

The general results of the various examinations are given in Table 2 and a comparison of the typical winter regional distribution of *H. eurysternus* is compared with the farmers' opinions in Fig. 3.

(*a*) *Haematopinus eurysternus*

The first obvious result of the examinations is the differentiation of a population of *H. eurysternus* into breeding colonies and nymphal clusters.

In January the top of the neck is the main breeding area, the females living singly or being clustered together, as many as fifty-eight being recorded in one group. The males are scarce, the male : female ratio varying from 1 : 7 to 1 : 15. The young nymphs are also rare, but a number of third instar nymphs can be observed. Secondary breeding areas can be seen around the base of the

horns, on the brisket and on the tail. If the top of the neck becomes overcrowded the main breeding area extends down the side of the neck, the top section of the side of the neck being used first, and the colony gradually working down to the brisket and dewlap. In cases of extremely heavy infestations any part of the body can be used for breeding, even the legs which are rarely infested. In an average infestation the side of the neck is the principal nymphal area, where the nymphs roam about singly or cluster together in groups. Each of these groups usually has one or more males in attendance. The males are also scattered singly over the side of the neck. The ears, in winter, support a migratory population, consisting usually of only an odd nymph and frequently a male, and rarely is any breeding observed there. The eyelids, and around the eyes in general are favourite places for very young nymphs, but not for the third instar. The shoulders are often used as a breeding area in cases of a heavy infestation, but more usually can be classed as a nymphal area. The back is rarely the habitat of any one stage, but all types can be found here and the lice are usually migrating between the neck and the tail areas. This applies also to the rump area, although breeding colonies and nymphal clusters may be established here as overflows from the tail area. The tail serves as a small and steady breeding area all the year round. Nymphal clusters are often seen on the perinaeum near the anus, where they are protected to some extent by the tail. Adult lice are sometimes found in this region, but rarely breed there. The thigh forms an overflow area from the tail and rump areas, and clusters of egg-laying females often congregate near the ischial process. The sides, belly and legs are rarely infested. Abnormal distributions, such as a heavy scrotal infestation, are sometimes seen, but the usual type of winter distribution in this country is that described above. These observations are in general agreement with the farmers' observations (see Fig. 3).

The gradual shift of the population from the typical winter distribution to the summer areas of infestation, and back again in the autumn is shown in Table 2. The summer areas of infestation can be described briefly as breeding areas on the tail, around the horns and along the inner margin of the ears; the nymphs usually remain near the breeding areas. One farmer stated that lice are found in the summer only round the horns and on the tail; another said that lice seem to congregate along the tips of the ears in spring and early summer.

(*b*) *Linognathus vituli*

There is insufficient evidence to provide a clear picture.

(*c*) *Solenopotes capillatus*

The characteristics of *S. capillatus* infestations is the clustering together of nymphs and adults, mainly on those areas anterior to the shoulders, although some lice have been observed on the shoulders. Repeated attempts to study the life history of this louse have always ended in failure, the lice isolated in

Table 2. *Regional distribution of lice on heifers running in fields*

Month	*Haematopinus eurysternus*	*Bovicola bovis*	*Linognathus vituli*	*Solenopotes capillatus*
January	Mainly on top and side of neck and shoulders infested. Few at tail-head and perinaeum	Lice on back, rump, loins, shoulders and top and side of neck	Lice on top and side of neck and perineal areas	Mainly cheek and side of neck areas infested. Few on brisket
February	Infestations spreading down side of neck	Shoulders and top and side of neck particularly infested	Lice on top and side of neck and perineal areas	Majority of lice on cheek. Brisket more heavily infested; also side of neck infested
March	Ears, base of horns becoming infested. Populations on top of neck and shoulders decreasing while those of tail and rump increasing	Marked decrease in population of top and side of neck. Ribs and belly becoming infested for first time	Lice on perinaeum chiefly	Majority of lice on cheek. Brisket more heavily infested; also side of neck infested
April	Shoulders clean. Top of neck still infested. Base of horns, ears and tail heavily infested	Top and side of neck, shoulders and loins clear. Few on head. Belly, sides, rump and tail infested	Lice on perinaeum only	Main infestation on brisket, few on cheek and side of neck
May	Only few animals maintaining lice on top and side of neck	Belly and sides clear. Two cases of head infestation. Others on rump and tail areas	—	Brisket only infested
June	Base of horns, tips of ears and tail only infested. Ears chiefly	Tail only infested	—	Brisket only infested
July	Base of horns, tips of ears and tail only infested. Ears chiefly	Tail only infested	—	—
August	General increase of population. Three cases of very light infestation on top of neck	Tail infestations increasing	—	—
September	Ear population decreasing. That at base of horns and top of neck increasing	Infestations spreading on to rump from tail area	—	—
October	Top of neck infestation increased considerably. Ears and base of horns populations less. Two cases of rump infestation spreading from tail area	Rump population increasing and lice migrating to thigh areas	—	—
November	Top of neck infestation getting heavy. That of shoulders and side of neck increasing. Rump and perinaeum populations increasing. Ears very lightly infested	Few infestations spreading up loins from rump and tail area	—	—
December	Ears free except for occasional nymph. Infestation of base of horns markedly reduced. Top and side of neck, shoulders well infested. Rump and perinaeum lightly infested	General increase of infestations	—	—

metal cells on the back or rump failing to survive. This may have been due to the inability of the louse to live on the back areas.

The cheek and side of the neck appear to be the main areas for winter infestations, and the brisket for summer infestations.

(*d*) *Bovicola bovis*

The most striking feature of the populations of *B. bovis* is the scarcity of males, a fact that was noticed by Bedford (1932). The examinations also indicated the tendency of populations of *B. bovis* to congregate in breeding colonies and nymphal clusters, and their greater ability, as compared with *H. eurysternus*, to breed on any part of the body. In the new breeding colonies, that is to say, small clusters of adult lice starting a new group in a breeding area, the male : female ratio varied from 1 : 6 to 1 : 20, and in the established breeding areas from 1 : 10 to 1 : 30. The nymphal areas, while being quite distinct, were unlike those of *H. eurysternus* in that many adults were also to be found amongst the nymphs. In these communities the sex ratio of the adults present varied from 1 : 20 up to 1 : 60. The sex ratio for the whole population, in the case observed, was 1 : 24.

In the winter the breeding colonies are chiefly on the sides of the 'top of the neck' area, the side of the neck, shoulders, back, rump and tail. The centres of active breeding are determined by the density of the lice, and the old breeding areas become the nymphal areas, so that all stages of the biting louse are found in the parts specified. The head becomes increasingly infected as the population gets bigger. The sides, thighs and belly are rarely affected. The summer areas of infestation are the head and tail, but it is particularly interesting to note how the population gradually migrates during the spring away from the winter areas of infestation. The sides and belly of the animals are quite heavily infested, but by the summer these areas are free again.

The *B. bovis* populations observed in 1939 did not show the typical winter distribution as the populations were started artificially in December 1938, but the general rise and fall of the total populations was in agreement with the observations of the previous year.

It has been explained that *B. bovis* is usually seen in larger numbers than the sucking lice, and that *B. bovis* causes less individual damage. Thus, for all the different species of lice to have an equally deleterious effect on the cattle, *B. bovis* must be present in much larger numbers than the other lice. Since all the lice start active breeding at the same time in the autumn, as has been shown in a previous section, *B. bovis* would have to breed more rapidly in order to affect the cattle to the same extent, and at the same time, as do the sucking lice. It is a fact that *B. bovis* has a shorter life cycle on the host, but it is not known whether these lice lay more eggs per female than *H. eurysternus* and the others. The implication that *B. bovis* is slower in reaching an effective population density level, *i.e.* one at which it causes damage to the cattle, can be inferred from its later seasonal appearance according to the farmer. It would

suggest that either (*a*) all the lice tend to increase in numbers at approximately the same rate, but that *B. bovis* must be present in such very much larger numbers that it requires a longer period of active breeding before reaching its effective population density, or (*b*) that females of *B. bovis* lay fewer eggs than the females of the sucking lice.

Casual observations on the regional distribution of lice in the winter months have been recorded by several workers, and are in agreement with those given above. The references are as follows:

Cattle lice in general: Akinschin (1914), Lamson (1918), Shull (1932).

Sucking lice in general: Imes (1925), McDougall (1923), Underhill (1923).

Haematopinus eurysternus: Roberts (1938).

Linognathus vituli: Roberts (1938).

Solenopotes capillatus: Bishopp (1921), O'Connor (1932), Roberts (1938).

Bovicola bovis: Imes (1925), Roberts (1938), Thompson (1933), Underhill (1923).

5. Factors affecting the population variations

The monthly average of maximum and minimum screen temperatures, the solar radiation as measured by a vacuum thermometer, the 9 a.m. humidity and the rainfall, as recorded at the Cooper Field Research Station, are given in Fig. 4.

(*a*) *Temperature*

The distribution of cattle lice in Great Britain given in Part I of this series showed that lice infestations were below the average on the east coast of Great Britain, and above the average on the west coast. The east coast in general is subject to lower winter temperatures than the west coast. The general tendency of lice infestations to become more severe, in the opinion of farmers, from north to south, is also a factor which should be considered. These general facts suggest a possible temperature effect, but the seasonal fluctuations of lice populations observed at the Research Station have no relation to the air temperatures.

The skin temperatures of heifers in the field have been recorded at each monthly examination. It was found that the weather at the time of the records affected these temperatures. On warm days, the skin temperatures along the back were higher than normal, and lower on cold days. In general, the forehead and tail skin temperatures were low in comparison with those of the rest of the body. This is interesting, as the tail always harboured lice, while the forehead was only affected in the winter. The 'top of the neck' temperature was taken in a fold of the skin, as the lice usually congregated there. This temperature, and that of the perinaeum were always the highest. The temperatures of the rump, back, shoulder and thigh were usually uniform, but fluctuated according to the air temperature and degree of sunshine. The temperature of the side of the neck was variable, while those of the belly, brisket and legs were low. The ear temperatures fluctuated considerably.

The skin temperatures were rarely below 31° C., and usually fluctuated between 33 and 36° C., so that any part of the body had a suitable skin temperature for breeding purposes at all times of the year.

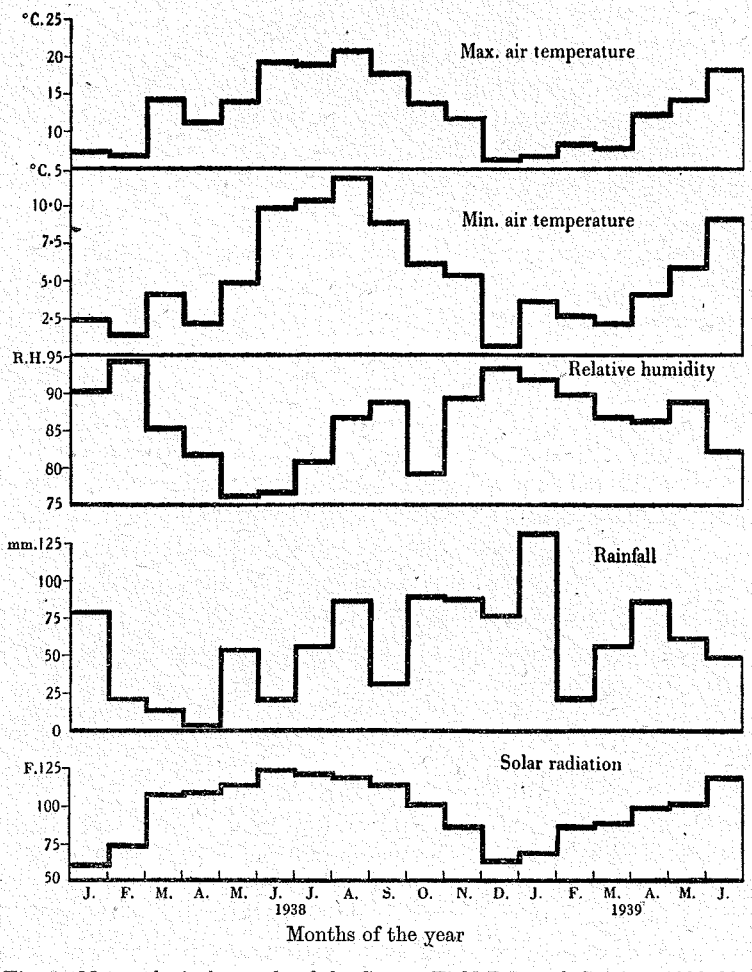

Fig. 4. Meteorological records of the Cooper Field Research Station, 1938–39.

(*b*) *Humidity*

The relative humidity in the coat of cattle has not been ascertained, as no reliable method was evolved.

The air humidity appears to have little correlation with the lice infestations for the humidity fell sharply in March while the lice were still active, and, in the case of *B. bovis*, while the population was definitely increasing. In June 1938, the humidity rose without a corresponding large increase in the populations, and, in October 1938, when the lice were obviously increasing rapidly, the humidity fell sharply.

(*c*) *Rainfall*

The meteorological records show that the degree of rainfall is not correlated with the fluctuations of the lice populations (Figs. 1, 2 and 4).

The importance of rainfall in relation to the quality of the pastures is dealt with in the discussion.

(*d*) *Light*

There are no records at the Cooper Field Research Station for the amount of cloud or for the amount of intensity of daylight, but the solar radiation measured by temperature can be taken as an indication of the degree of light intensity.

There appears to be a close correlation between the infestation levels and the solar radiation temperatures. As the light starts decreasing in July, so the lice start increasing, and in the *H. eurysternus* chart the increase of the lice population is closely allied to the proportional decrease of light. However, in February and March, the light increased while the lice were still very active. In March there was a general dispersal of the populations away from the neck regions which is suggestive of a response to the light. The increase of light in April was negligible, but the lice populations decreased sharply. This apparent anomaly is discussed later.

The records of lice populations in January and February 1939, are of particular interest. The January records show (Tables 1 and 2) the normal lice populations and regional distribution for this period of the year. In February, the lice population increased, as would be expected, but the regional distribution on the host changed. *H. eurysternus* was found in January, on the top of the neck, shoulder, and rump, but in February the lice had decreased in these areas, and the lower regions of the body, the side of the neck and the brisket had become heavily infested. The *Monthly Weather Report* for February 1939 states: "...The excessive sunshine in east and south-east England and parts of the Midlands was noteworthy...." At Harpenden, the nearest Meteorological Station to this Research Station, giving sunshine records, recorded 51 % above the average for the month. The shift of the lice populations from those areas where the light would affect them to areas which were darker in this exceptionally bright month is highly suggestive.

During examinations of lice in the field, it was observed that *B. bovis* always moved away from areas exposed to the light by parting of the hairs; *H. eurysternus* exhibited the same negative phototropism, but was slower to react. Crude qualitative tests in the laboratory corroborated the existence of this negative phototropism.

(*e*) *Coat of the host animal*

The length and thickness of the coat of a cow vary at different times of the year, and a rough estimation of these variations was made at each monthly examination of cattle.

When the lice were most active the coat was thick and long, and in the summer months, when the lice were less active, the coat was thin. During the summer months the lice were found around the horns, on the tips of the ears and on the tail. Each of these areas was covered with thick long hairs, which would afford the lice excellent protection from the direct rays of the sun, and from any marked variations in the air temperature.

The long hairs seen on the tips of the ears in summer disappear in winter. The base of the horns and the tail are well covered with long hairs at all times of the year, and lice were found in these areas all the year round. The usual sites of lice infestations in the winter months have been shown to be the top and sides of the neck, the shoulders and rump. In the winter these areas are covered with a thick coat, but in summer the hair is much thinner. It seems that the general thickness of the coat is of great importance to lice activity. This fact was commented upon by Cooley & Parker (1916).

The length of individual hairs is not of great importance. *B. bovis*, *L. vituli* and *S. capillatus* are usually found in areas where the hairs are short, while the adults of *H. eurysternus* are usually found on the areas with long hairs.

The importance, if any, of the individual hairs is probably due to thickness, for, in general, the long hairs are coarse and thick, while the short hairs are thin. The thickness of the hair might influence the ability of lice to clasp the hair, but this appears unlikely as all ages and species of louse can be found on any part of the body.

The annual shedding of the coat probably also helps to reduce the lice infestations, as numerous eggs, and possibly some of the lice themselves, will be lost as the hairs of the animal fall out (cf. Cooley & Parker, 1916).

The importance of the coat of the host animal can be summarized as follows:

(*a*) The thickness of the coat regulates the temperature gradient between the skin of the animal and the air.

(*b*) The thickness of the coat affords protection to the lice in preventing the access of light.

(*f*) *Skin of the host animal*

It was apparent from personal observations and experiments that the distribution of lice cannot be associated with the thickness of the hide.

Some authors (Underhill, 1923; Shull, 1932; Roberts, 1938) have suggested that lice are affected by the greasiness of the skin of the host because cattle lice are most active in winter when the animal's skin is dry and scaly, whilst in the spring, when the coat is shed and the skin becomes oilier, the lice decrease in numbers.

No reliable method has been evolved of estimating the greasiness of the skin or of the hair, so that no direct evidence bearing on this theory can be given.

Animals which have dry skins are those fed on a high proportion of concentrated foods or on poor quality food. This condition would occur naturally in winter when fodder is scarce. In the spring, the new grass gives a more

succulent type of food, and coincident with this fact is the reduction in the number of lice on the cattle. There is no doubt that animals which are poorly fed get into a low condition of health, which would make them more susceptible to lice infestations. Conversely, well-fed animals given a large ration of concentrated foods should be less susceptible to lice infestation. Cattle lice are, however, often found on these animals, and it is suggested that this is due to the fact of their skin being less greasy than those of grass-fed animals.

Evidence has already been given that the constant feeding of lice confined in the metal cells used for the critical observations, produced, in February and March only, a definite skin reaction. These vesicles ruptured easily and then formed a hard crust. The skin of the necks of animals that have been heavily infested with lice are often crusted and hard, possibly as a result of the formation of a large number of such vesicles. These crusted areas are rarely infested. It is curious that no vesicles are formed as a result of the constant feeding of the lice except in the months of February and March. During these months the natural moulting of the coat takes place. It seems possible that the process of moulting may be coincident with some physiological change in the skin tissues, and that the feeding of the lice may cause obvious and more violent skin reactions while the skin is in this particular physiological state.

After moulting is complete the skin becomes oilier. Further evidence is required before deciding whether the lice decrease as a result of the theoretical physiological change of the skin at the time of moulting, or as a result of a higher oil content of the skin after moulting, or a combination of the two in conjunction with other factors, such as the spatial limitations of 'summer areas' protected from sunlight.

(*g*) *Food of the host animal*

See previous section.

(*h*) *Age of the host animal*

Calves are susceptible to three types of infestation, and less susceptible to *H. eurysternus* infestations, while heifers are susceptible to all four types of infestation. This might explain why farmers see more lice on heifers and, therefore, consider them to be the most susceptible type of animal. It would be fairer to summarize the position by saying (*a*) that calves are housed, so are liable to rapid increases of infestation which are observed because of the frequent handling of them, and (*b*) heifers being susceptible to *H. eurysternus* infestations, which are soon obvious even when there are few lice, are believed to be susceptible types, but, in reality, are probably more resistant than calves. Thus when referring to susceptibility the type of infestation should be specified.

(*i*) *Colour of the host animal*

Numerous observations have been made, but no significant difference was found in the frequency with which any one colour of animal was infested or even the colour of hair to which the lice were attached.

(*j*) *Accessibility of lice to the host animal*

It has been suggested by McDougall (1923) and Imes (1925) that lice are found on those parts of the body where the cow cannot lick them. Observations on cattle tied up in cowsheds indicated that there is no area on which lice are found which the cow cannot either lick or rub.

(*k*) *Housing of cattle*

The questionnaire showed that farmers were almost unanimous in stating that cattle kept in houses were more heavily infested with lice than those animals running in the fields. This has been confirmed by personal observations.

6. Discussion

The most striking feature of the critical work on the life histories was the effect of the air temperature on the incubation period of the eggs. The more accurate laboratory observations on the incubation period of the eggs of *H. eurysternus* showed that the rate of development and hatching of the eggs was entirely influenced by temperature. The humidity appeared to have little effect except at the extreme limits of dry or saturated air. Eggs would not hatch below 27·5° C., and, in addition, all development of the egg appeared to cease below this temperature. The activities and development of *H. eurysternus* did not appear to be so strongly influenced by the air temperature, although some correlation was shown to exist between the rate of oviposition and the general air temperature.

Cattle lice live upon the skin surface of their host, and are sheltered by the coat of the animal from the varying effects of the climate. The length and thickness of the animal's coat will automatically regulate the temperature gradient between the skin and the outer hair. The lice live on the skin, so that they are always in close proximity to their main source of warmth. It has been shown that the skin temperature rarely falls below 30° C., and on most parts of the body where the lice are found the temperature is between 33 and 36° C. The lice which always live on the skin are never subjected to wide fluctuations in temperature, and if, for any cause, the temperature should fall appreciably, the lice are mobile and can move to a more congenial habitat.

The eggs are laid near to the skin, but as they develop they are gradually moved away from the skin by the natural growth of the hair. Thus, they are subjected to a gradually decreasing temperature, and would be more obviously affected by the diurnal fluctuations of temperature. This general theory would suggest that all lice activity is dependent upon the microclimatic temperature, and that this microclimate is, to some extent, influenced by the air temperature.

While temperature is fundamentally the most important factor governing the activity of individual lice, in the warmest times of the year the lice populations are actually very small. Other climatic factors or changes in the conditions on the host, or a combination of these, must so strongly influence

the cattle lice as to override the favourable influence of the temperature factor at this season.

The length and thickness of the coat of the host animal has been shown to vary at different times of the year, the coat being thickest when the lice were most active and vice versa. These variations are a natural response to the variations in climatic conditions.

It has been observed that the microclimatic temperatures in the summer are as high as in winter, so that the lice should be able to breed and live normally throughout the year. However, in the summer months the lice are found at the base of the horns, on the ears and tail areas, which are covered by a dense coat. The dense coat in these areas does not raise the microclimatic temperature above those pertaining in the thin coated areas, because the skin temperatures of the tail and ears, two of the areas with thick coats, are known to be lower than the average for the body surface at all times. The coat appears to be acting as a filter of the light intensity, which supports the previous arguments that the light factor is important in regulating the seasonal activities of lice.

Thus it is believed that the most important of the meteorological factors is light intensity. Laboratory tests and personal observations have substantiated the negative phototropism, and a close correlation has been shown between the seasonal variations of lice populations and the intensity of light. The light intensity increases as the thickness of the coat and the lice populations decrease, and vice versa. Further, in February 1939, records of lice populations showed a change in their regional distribution on the host which was correlated with an exceptionally high light intensity during the month.

It is not suggested that the combined factors of light intensity and thickness of coat are the only ones that regulate the activities of lice, but it is suggested that these combined factors are of very great importance, and do influence the lice populations all the year round.

The other climatic factors, i.e. the rainfall and humidity, did not appear to affect the seasonal variations. It is possible that the rainfall has some importance, as suggested by Roberts (1938) because of its effect on the pastures. Thus rainfall and food are two interdependent factors.

Also the general health of the cattle influences the louse infestations. Whether this be due entirely to the quality of the food, or, as suggested by Roberts (1938) and Underhill (1923), to the nature of the skin secretions as a result of feeding, or both, it is not possible to say. From winter to summer there is a gradual improvement in the quality and nature of the food, the skin becomes greasier, and in the spring there is the annual shedding of the coat which, it has been suggested, may be correlated with a physiological change in the skin. The last statement is based on the obvious skin reaction observed after lice have fed during February and March, and on the crust formations seen on the necks of heavily infested animals.

From the above discussion it may be assumed (*a*) that the interrelated

factors of light intensity and the thickness of the coat of the host animal strongly influence the activities of lice at all times of the year; (*b*) animals in poor health, usually as a result of feeding on poor quality food, are more susceptible to lice infestations than animals in good health; (*c*) that the rainfall is important in countries of periodic rainfall as it improves the quality of the pastures; (*d*) that the quality of the food affects the general health of the animals, and also influences the texture of the skin; and (*e*) that the condition of the skin influences, in some unknown manner, the activities of lice.

It is known, in spite of the scanty records, that cattle lice are found in the majority, if not all, of the cattle rearing countries of the world. It is not so well known which species of lice are found in these countries. The discussion above, on the climatic and physical factors affecting lice populations, would suggest that all species of cattle lice might occur wherever suitable cattle are found, for there does not appear to be any climatic factor limiting any one species of louse to a particular climate. There are records of all the cattle lice from tropical and temperate climates, but none from arctic or antarctic climates.

The distribution of the lice in Great Britain, Craufurd-Benson (1941), did suggest that some factor influenced the distribution of *H. eurysternus*, but not the other species. It is believed that the distribution is affected by the varying farm practice in different areas. There is insufficient evidence to indicate that climatic factors have controlled the distribution, although the distribution in relation to temperature has been commented upon.

The size of the sucking lice of cattle appears to be influenced by the climatic conditions. Roberts (1938) has stated that specimens of *H. eurysternus*, found in tropical regions, are larger than those found in temperate climates. Some specimens of *L. vituli* taken from cattle by Mr W. Downing, F.R.C.V.S., of this Research Station, in Alcopola, Argentine, are considerably larger than those found on the Research Station. Dr Roberts of Yeerongpilly, Queensland, kindly sent me specimens of *S. capillatus* taken from cattle in that country, and these lice are larger than those found in England.

Thus, both *L. vituli* and *S. capillatus*, show size differences in different countries.

7. SUMMARY

1. The seasonal variations and regional distribution of the cattle lice have been studied by monthly examinations of cattle at the Cooper Field Research Station.

2. Additional evidence has been obtained by the distribution of a questionnaire to farmers, the general results of which are included in this paper.

3. The seasonal variations of the populations of the four species of cattle lice in Great Britain are similar. The maximum population density is reached in February and March. In April and May there is a rapid decline until the populations reach their lowest level in June, July and August. In September, the lice start increasing in numbers till they reach their maximum density in February and March.

4. The regional distribution of the population varies in accordance with the seasonal variations of the whole population.

5. The various climatic factors that may affect the lice populations are discussed. It is considered that the light intensity is a factor of major importance in this country.

6. The various factors inherent in the host animal are discussed, and it is suggested that the seasonal fluctuations of the density of the animal's coat are important.

7. The finding of a previous paper (Craufurd-Benson, 1941) that the microclimatic temperature is important as affecting the hatching of eggs is discussed in relation to the variations of lice populations as a whole.

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REFERENCES

AKINSCHIN, TH. (1914). Parasites. Lice on animals and their destruction. *The Agriculturist, St Petersburg*, **7**, 287. *Rev. App. Ent.* Ser. B, **2**, 118.

BEDFORD, G. A. H. (1932). *Rep. Dir. Vet. Ser. Anim. Industr. S. Afr.* p. 18.

BISHOPP, F. C. (1921). *Solenopotes capillatus*, a sucking louse of cattle not heretofore known in the United States. *J. agric. Res.* **21**, 797–801.

COOLEY, R. A. & PARKER, R. R. (1916). Cattle lice in Montana. *Rep. Montana Live Stock Sanitary Board and State Vet. Surgeons, Helena*, 1915–16, pp. 19–21.

CRAUFURD-BENSON, H. J. (1941). The cattle lice of Great Britain. Pt. I. Biology, with special reference to *Haematopinus eurysternus*. *Parasitology*, **33**, 331.

IMES, M. (1925). Cattle lice and how to eradicate them. *Farmers Bull. U.S. Dep. Agric.* no. 909.

LAMSON, JUN., G. H. (1918). Cattle lice and their control. *Bull. Storrs Agric. Exp. Sta.* no. 97.

MCDOUGALL, R. S. (1923). *Insect and other pests of* 1922. Separate from Trans. Highland and Agric. Soc. Scotland. 43 pp.

O'CONNOR, B. A. (1932). *Solenopotes capillatus* Enderlein, a sucking louse of cattle hitherto unrecorded from Australia. *J. Dep. Agric. W. Aust.* (2) **9**, 300–2.

ROBERTS, F. H. S. (1938). Cattle lice; their economic importance in Queensland. *Aust. Vet. J.* **14**, 55–8.

SHULL, W. E. (1932). Control of the cattle louse, *Bovicola bovis* Linn. (Mallophaga, Trichodectidae). *J. econ. Ent.* **25**, 1208–11.

THOMPSON, R. W. (1933). Sodium fluoride as a control for cattle lice. *Rep. ent. Soc. Ontario* 1932, **63**, 54–6.

UNDERHILL, B. M. (1923). Some parasites of hogs, sheep, cattle and poultry. *Gen. Bull. Pennsylvania Dep. Agric.* no. 354, p. 40.

WALTON, C. L. (1924). Preliminary Report on the agricultural zoology of North Wales. *Univ. Coll. N. Wales Dep. Agric.* no. 28, Bangor.

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