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THE ECOLOGY OF THE LOUSE *POLYPLAX SERRATA* (BURM.) ON THE MOUSE *MUS MUSCULUS* L.

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Summary

The number of *Polyplax serrata* (Burm.) on the mouse *Mus musculus* L. is determined by the efficiency with which the mouse grooms itself with its mouth. The efficiency with which the accessible hindpart of the body is groomed is such that normally the majority of all stages of the life cycle are found on the forepart of the mouse with the exception of the stage I nymph which is distributed over the whole body.

The principal requirements for self-grooming to control the number of lice are that the technique is efficient, that sufficient time is spent grooming, that an adequate area of the body is groomed, and that lice move readily into the accessible area. Any factor which influences adversely any one of these requirements causes the efficiency of grooming to decrease, and thus permits lice to increase in numbers and to populate the whole body.

I. INTRODUCTION

The distribution of lice on some species of rodents has been described by Dubinin (1953), who found that on small rodents such as mice and voles it was restricted, usually to the forepart of the body and the root of the tail, but on rats the lice were dispersed over the dorsal and lateral aspects of the body. Vysotskaya (1950) reported that there was a seasonal change in the distribution of the louse *Hoplopleura acanthopus* (Burm.) on the body of the vole, *Microtus arvalis* (Pall.); the lice were found only on the forepart of the body in the autumn but were present over the whole body in early spring. In addition, the lice were found to be most abundant in the late winter and spring. A similar variation in the number of this louse has been found to occur on the male meadow vole *M. pennsylvanicus* (Ord) (Cook and Beer 1958). Seasonal variations in the number of lice on rodents have been reported to occur also on the rats *Rattus norvegicus* Berkenhout (Harkema 1936; Zakovich 1946), *R. rattoides turkestanicus* (Satunin), and *Nesokia indica* (Gray & Hardwicke) (Dubinin 1950); the squirrels *Sciurus carolinensis* Gmelin (Harkema 1936) and *S. vulgaris mantchuricus* Thomas (Dubinin 1950); and on three subspecies of the vole *M. socialis* (Pall.) (Kirshenblat 1938; Olsuf'ev 1940). However, an absence of significant seasonal variations in numbers has been reported on female meadow voles, *M. pennsylvanicus*, and on the deer mouse, *Peromyscus maniculatus bairdii* (Hoy & Kennicott) (Cook and Beer 1958). Thus, variations both in the abundance of the lice on rodents and in the extent of their distribution over their host's body have been recorded.

This paper reports the results of a study of the factors which govern the abundance and distribution of the louse, *Polyplax serrata* (Burm.), on the mouse, *Mus musculus* L.

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II. Life Cycle of P. serrata

(a) General

P. serrata is a louse of the order Anoplura, family Hoplopleuridae, a family of blood-sucking lice whose members are found mainly on rodents. The five stages of the life cycle are the egg, three nymphal stages, and the adult. The nymphal stages can be readily differentiated, both by size and by the distribution of the setae on the abdomen (Fig. 1). The male and female adults differ markedly in size, the length of the female being approximately one and a half times that of the male. The eggs are attached to the hair near the skin with the pole of attachment nearest to the skin.

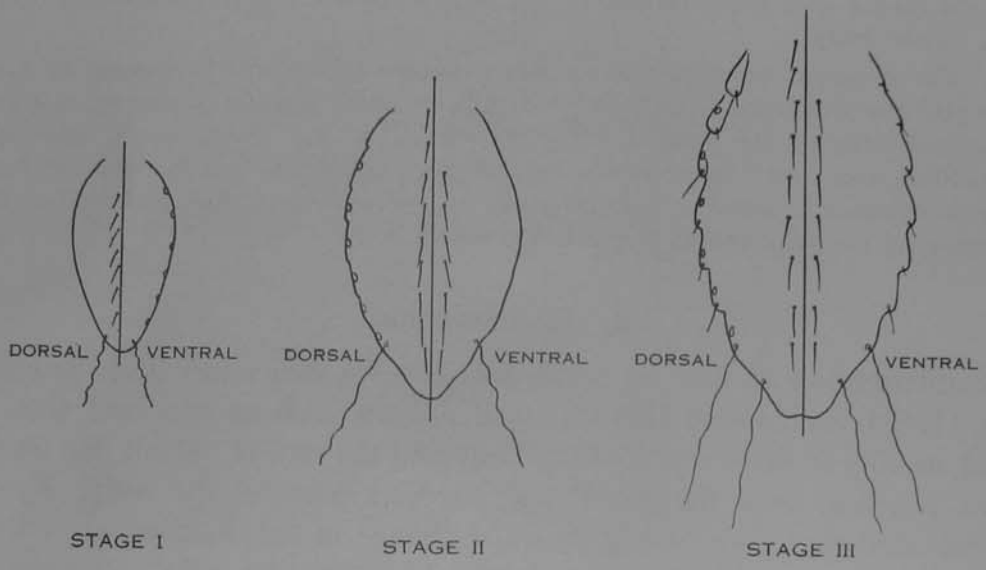

Fig. 1.—Distribution of setae on dorsal and ventral aspects of the abdomen of the nymphs of *Polyplax serrata*.

(b) Length of Life Cycle

Hairs, with attached eggs, were removed from a mouse and exposed to 35°C, which is within the range of the temperature gradient near the skin of mice (Murray, unpublished data). The humidity was controlled with a saturated sodium dichromate solution to about 54% R.H. (Solomon 1951). A daily examination was made of the 58 eggs exposed and all had hatched by the fifth day.

Stage I nymphs, which had hatched from eggs incubated in the laboratory, were placed on louse-free mice which were fitted with Elizabethan collars round their necks to prevent grooming (Plate 1, Fig. 1). When 25 stage I nymphs were placed on a mouse and 40 on another and the mice killed and examined 7 days later, only adults were found, 10 males and 1 female on one and 7 males and 21 females on the other. About 80 stage I nymphs were placed on a third mouse, and only adult lice, 11 females and 4 males, were found 7 days later. One of the females laid an egg whilst being examined and a fully developed egg was present in the abdomen of each of five others. Approximately 80 stage I nymphs were placed on the head of a fourth mouse which was examined 6 days later when only seven females were found, and a fully developed egg was found within the abdomen of five of them.

Therefore, as the eggs of *P. serrata* can hatch within 6 days and stage I nymphs can develop into adults within 7 days, the life cycle of *P. serrata* can be completed in 13 days.

III. Normal Number and Distribution of P. serrata on the Mouse

(*a*) *Methods*

The hair from the skins of four mice was examined after treatment with xylol (Murray 1957), to determine whether dead lice were retained in the hair coat, but only living lice were found. Hatched and dead eggs, however, remained attached to the hair but these could be readily differentiated from living eggs in which an embryo of normal appearance was visible. As dead lice were not retained

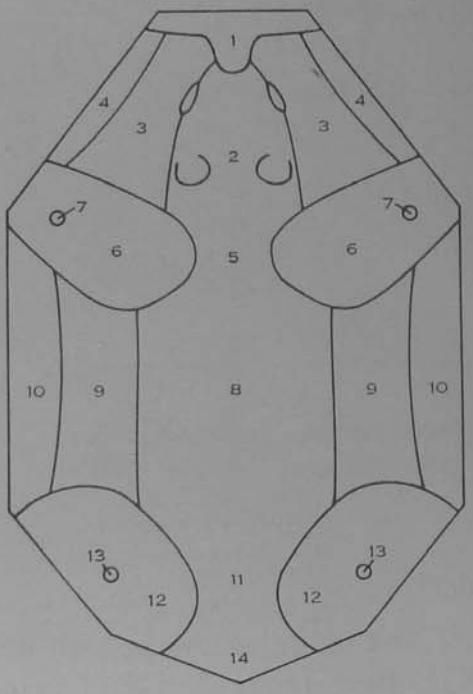

Fig. 2

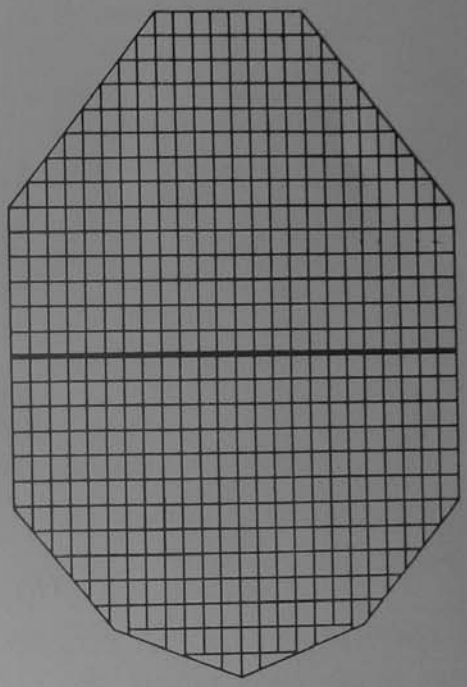

Fig. 3

Fig. 2.—Constant shape to which the skins of the mice were stretched: *1*, nose and around mouth; *2*, forehead, poll; *3*, cheeks, side of neck; *4*, ventral neck; *5*, between shoulder blades; *6*, shoulders, chest; *7*, fore legs; *8*, back; *9*, sides; *10*, belly; *11*, lumbar region; *12*, rump, flank; *13*, hind legs; *14*, root of tail.

Fig. 3.—Grid containing 524 areas. Heavy line denotes line of division into fore- and hindparts.

in the hair coat and dead and living eggs could be differentiated, the number and distribution of all the stages of *P. serrata*, which were living on a mouse when it was killed, could be determined by the following method.

Mice were stunned and their coats were soaked with ether or chloroform to kill all the lice *in situ*. The mice were then placed in a sealed jar together with ether or chloroform until they were dead. Their skins were removed in a similar manner and stretched to conform to a constant shape (Fig. 2), within which had been drawn a grid of 524 units (Fig. 3). All the units, with the exception of 10, were of equal area. In Figure 3 will be seen also a line drawn to divide the body

into fore- and hindparts which were approximately equal in area. The markings of the grid were clearly visible through the skin when it was dry. The hair was dry-shaved from over each area and mounted on a slide in Berlese's mounting medium. Separate preparations were made of the hair from each leg, but the skin on the ears, feet, and tail was examined directly with a stereoscopic microscope.

When it was desired to determine only the number of lice, the skin was stretched over the grid and examined directly with a stereoscopic microscope or the hair was shaved off the skin and examined in xylol.

TABLE 1

DISTRIBUTION AND NUMBER OF EGGS OF POLYPLAX SERRATA ON MICE

Mice N_1, N_2, N_5, N_6, and N_7 were permitted to groom themselves whereas mice C_4, G_1, and G_2 were prevented from grooming by means of an Elizabethan collar

Mouse	Forepart of Body	Hindpart of Body
N_1	299	0
N_2	489	0
N_5	59	0
N_6	356	14
N_7	382	4
C_4	4307	2088
G_1	Between 2500 and 2600	Between 2000 and 2100
G_2	Between 500 and 550	Between 150 and 200

(*b*) *Results*

(i) *Number of Lice.*—A complete count was made of the lice on mice and the average number per mouse was 118·8 (S.D. 49·4; range 36–270). In addition the composition of the louse population on each of four of these mice was determined. There were many more eggs present than lice and more stage I nymphs than the other nymphal or adult stages of the life cycle (Tables 1 and 2).

(ii) *Distribution of Lice.*—All stages, with the exception of stage I nymphs which were scattered over the whole body, were found predominantly on the forepart (Tables 1 and 2). Figure 4 shows where lice were found on mouse N_2, and the predominance of eggs, adults, and stage III nymphs on the forepart of the body and the scattered distribution of stage I nymphs may be seen. Stage II nymphs were more scattered on mouse N_2 than on the other mice. However, of the four nymphs found on the hindpart of the body, two were on the anterior region of that part. Eggs were found mainly around the eyes and ears and between the shoulder blades.

IV. EXPERIMENTAL

It was observed that mice employed two types of self-grooming. They scratched themselves with their hind feet and then licked the toes, and they swept

their mouth through the hair with an upward motion of the head. The restriction of lice normally to the forepart of the body suggested that lice were removed efficiently by grooming only from regions which could be reached by the mouth.

(*a*) *Effect of Prevention of Self-grooming with the Mouth*

To prevent self-grooming of the hindpart of the body with the mouth, Elizabethan collars made of copper wire (Plate 1, Fig. 1) were placed around the

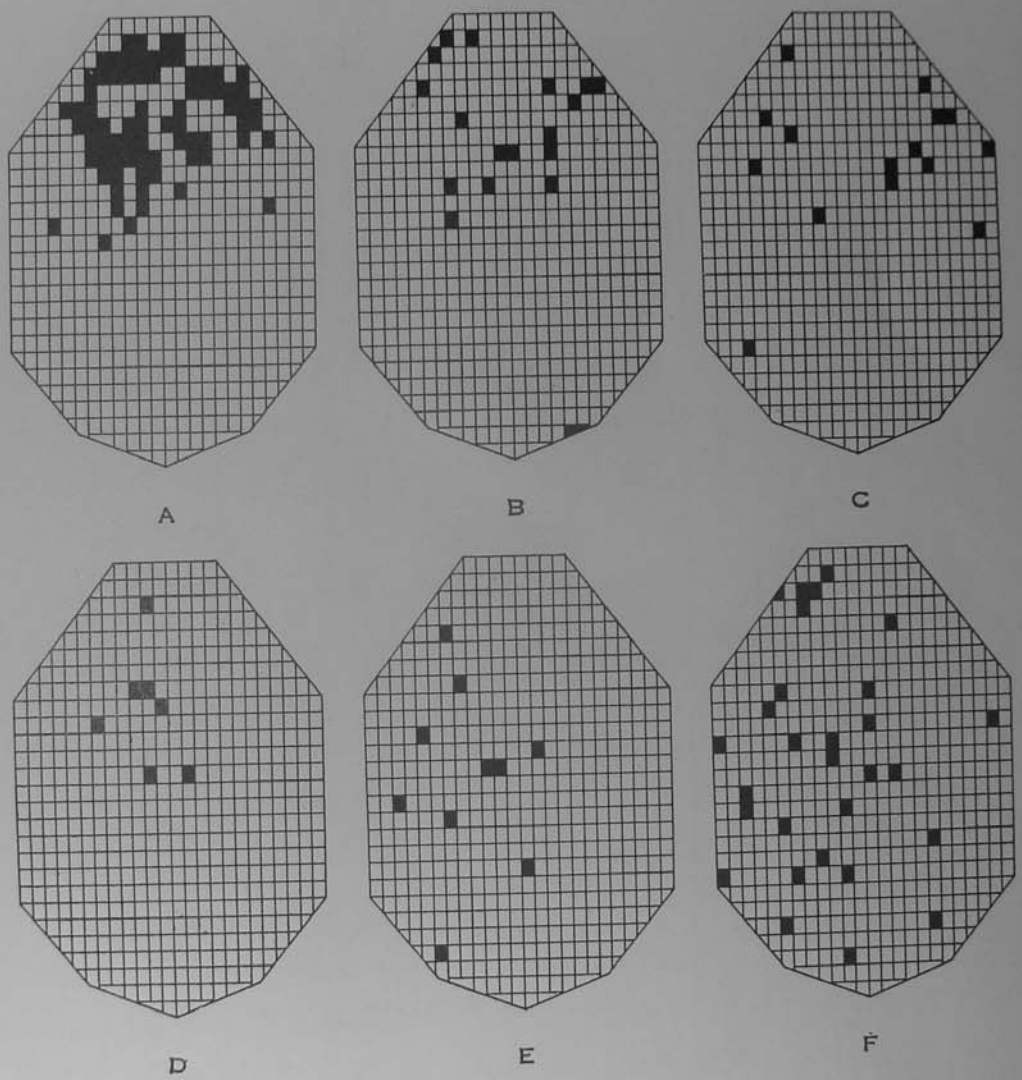

Fig. 4.—Normal distribution of *P. serrata* on the mouse. The black areas are those in which one or more eggs or lice were found. *A*, eggs; *B*, females; *C*, males; *D*, stage III nymphs; *E*, stage II nymphs; *F*, stage I nymphs.

necks of seven mice with normal infestations. The collars did not interfere with their ability to feed and to drink, provided the food and water were placed on the floor of the cage. The mice were killed 3–4 weeks later and the number and distribution of the lice were determined.

The number of lice on one mouse had increased to 868, on five to between 2000 and 4000, and on another to as many as 12,650. The composition of the

TABLE 2

DISTRIBUTION AND NUMBER OF NYMPHS AND ADULT POLYPLAX SERRATA ON MICE

Mice N_1, N_2, N_3, and N_4 were permitted and mice C_1, C_2, C_3, and C_4 were not permitted to groom themselves. Mice E_1 and E_2 were allowed to groom themselves for 24 hr only, after their louse populations had been made to increase by preventing self-grooming

Mouse	Forepart of Body					Hindpart of Body					Whole Body					Total All Stages
	Adults		Nymphs			Adults		Nymphs			Adults		Nymphs			
	♂	♀	III	II	I	♂	♀	III	II	I	♂	♀	III	II	I	
N_1	21	15	10	5	29	1	1	0	1	8	22	16	10	6	37	91
N_2	15	17	9	6	21	2	1	0	4	11	17	18	9	10	32	86
N_3	8	3	5	5	4	0	0	0	0	11	8	3	5	5	15	36
N_4	11	15	15	13	12	0	3	2	2	16	11	18	17	15	28	89
C_1	1413	1485	737	470	595	1949	3138	980	754	1129	3362	4623	1717	1224	1724	12,650
C_2	477	422	306	444	665	347	509	245	327	356	824	931	551	771	1021	4,098
C_3	120	116	55	68	79	60	92	87	74	117	180	208	142	142	196	868
C_4	573			576		532			646		1105			1222		2,327
E_1	559	365	176	135	165	123	206	79	77	131	682	571	255	212	296	2,016
E_2	361	270	116	123	107	73	110	43	46	140	434	380	159	169	247	1,389

louse populations on four of these mice was determined and Tables 1 and 2 show that the number of each stage had increased. Furthermore, numerous lice of all stages were found on the hindpart of the body (Tables 1 and 2; Fig. 5).

Elizabethan collars were placed around the necks of three mice with normal infestations. They were kept apart and weighed regularly for 3 weeks when they were killed. The number of lice on two mice (G_1, G_2) had increased to 1000–1250

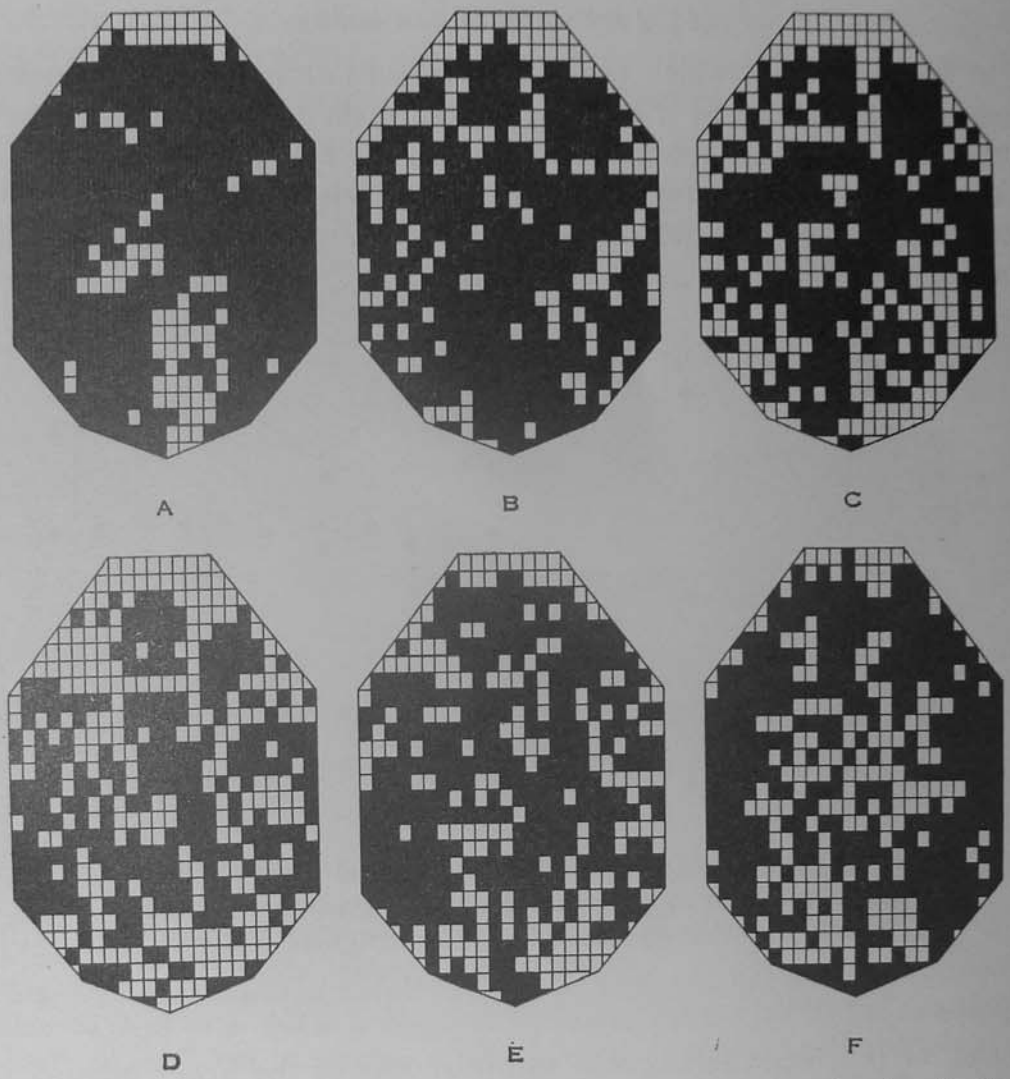

Fig. 5.—Distribution of *P. serrata* on the mouse after grooming has been prevented. The black areas are those in which one or more eggs or lice were found. *A*, eggs; *B*, females; *C*, males; *D*, stage III nymphs; *E*, stage II nymphs; *F*, stage I nymphs.

and on the third (G_3) to 500–550. The body weights of all mice remained within the limits of normal fluctuations (Fig. 6), and their demeanour appeared normal.

Elizabethan collars were fitted around the necks of five other mice and the louse populations were permitted to increase to between 1000 and 4000. The collars were then removed. After 24 hr two mice were killed and adult lice and stage III and stage II nymphs were found predominantly on the foreparts of both mice (Table 2). The distribution of the stage I nymphs, however, did not show

this trend. Thus, after only 24 hr grooming the distribution of the lice was apparently returning to normal. The remaining three mice were examined 4 days later when it was found that the number of lice had been reduced to less than 500.

Prevention of self-grooming with the mouth permitted the number of lice to increase rapidly and allowed them to populate the whole of the body. The number of lice was reduced rapidly when grooming was permitted to recommence.

(*b*) *Technique of Grooming*

The efficiency with which eggs were removed from the hair suggested that grooming was carried out by a combing action of the teeth rather than by licking and nibbling. The upper incisors of the mouse are fused together, whereas there is considerable movement between the two lower incisors. This fact, together with the upward sweep of the head of the mouse when grooming, suggested that the lower incisors were used.

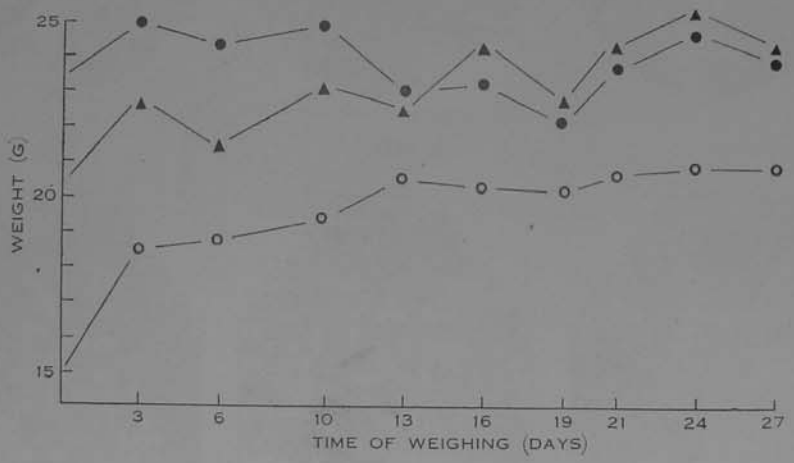

Fig. 6.—Body weights of mice during period when number of lice increased due to the prevention of self-grooming. ▲ Mouse G_1, 1000–1050 lice; ● mouse G_2, 1200–1250 lice; ○ mouse G_3, 500–550 lice.

A ring of polythene tubing was slid over one of the lower incisors of each of five mice and pushed down to the gum so as to wedge the teeth apart (Plate 1, Fig. 2). When the mice were examined three weeks later, the number of lice had increased and all stages were found on the hindpart of the body. It was apparent on visual examination that the number of lice was not as great as when Elizabethan collars were used to prevent self-grooming.

An Elizabethan collar was placed around the neck of a mouse and when the infestation had become heavy, the mouse was allowed to groom itself. One hour later it was killed, and many intact and mutilated lice and eggs were found in its stomach contents.

Lice, therefore, appeared to be removed by combing the hair between the lower incisors and were then ingested.

(c) *Effect of Reduction of the Efficiency of the Grooming Technique*

Ten mice were arranged in an ascending series according to body weight and were randomly divided into two groups. A polythene ring was placed around one of the lower incisors of each mouse in one group, after which they were all individually infested with 100–200 adult lice. The individual mice were kept in separate cages and examined regularly to ensure that the polythene ring was in position. All were weighed every 2 or 3 days until the experiment ended 38 days later, when the number of lice on each mouse was determined. During the course of the experiment, two mice in the experimental group died, and one in the control group. Figure 7 shows that the body weights of all mice remained fairly

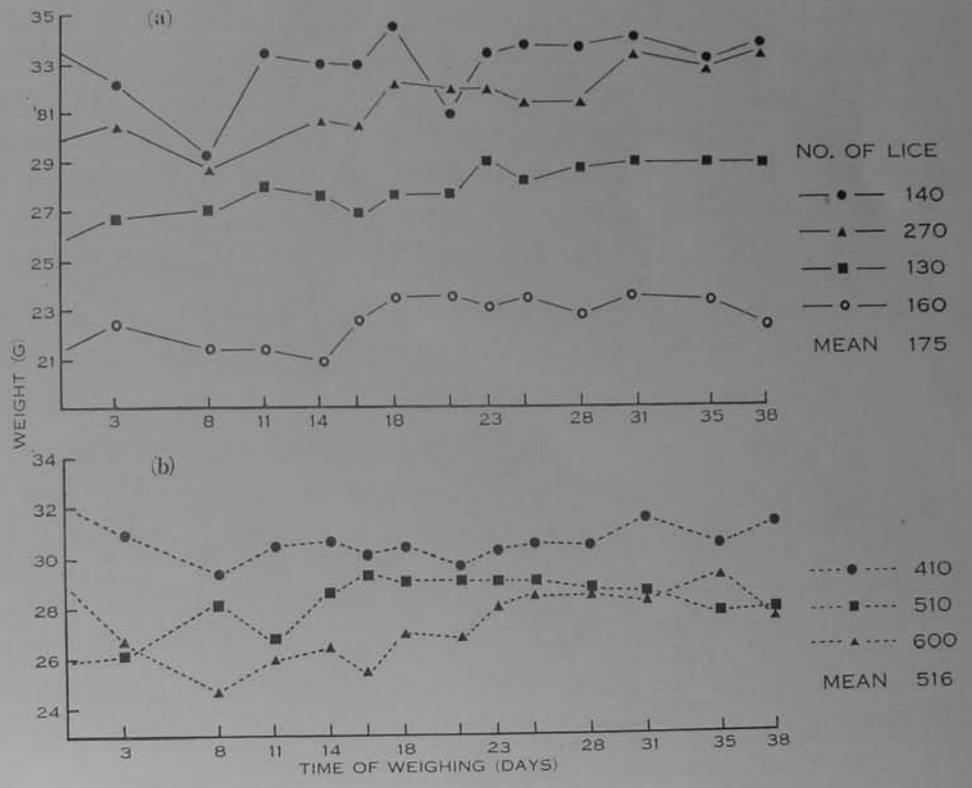

Fig. 7.—Body weights of mice during period when number of lice increased due to inefficient self-grooming. (*a*) Normal mice; (*b*) self-grooming rendered inefficient by placing a polythene ring around one of the lower incisors.

constant. There were, however, nearly three times as many lice on the experimental mice as on the controls, and numerous eggs and adult lice were found on the hindpart of the bodies of the experimental mice.

(d) *Effect of Reduction of the Area of the Body which can be Groomed*

Elizabethan collars were placed around the necks of three mice in such a manner as to prevent grooming of the left half of the hindpart of the body. Within 4 weeks the number of lice had increased from normal to over 1000, spread evenly over the region which could not be groomed, and only a few were found in the region which could be groomed.

Elizabethan collars were placed around the necks of another three mice to permit them to groom about three-quarters of the hindpart of the body. The number of lice increased but even after 42 days had not exceeded 500. Thus more than half of the hindpart of the body had to be groomed to control the number of lice.

(*e*) *Spread of* P. serrata *on Mice*

Elizabethan collars were placed around the necks of five louse-free mice and about 300 lice, predominantly adults and stage III nymphs, were placed on

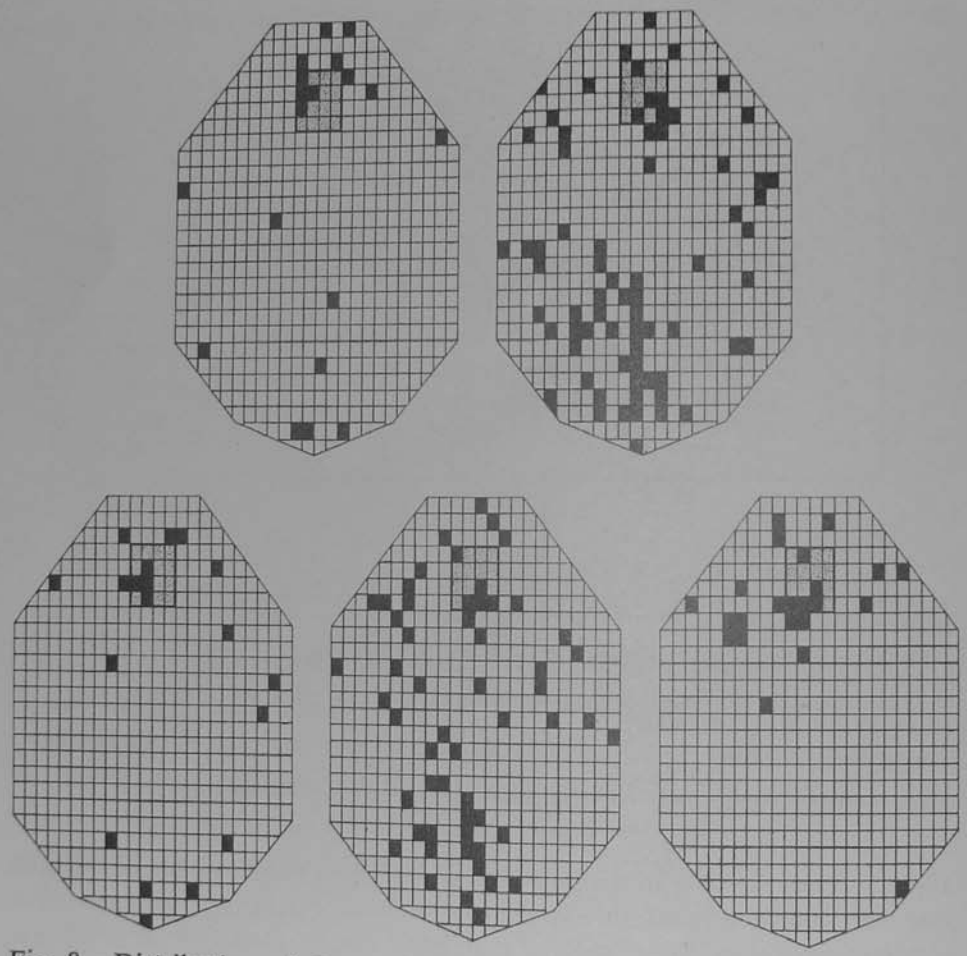

Fig. 8.—Distribution of *P. serrata* 24 hr after having been placed on the heads of mice. The stippled area, bounded by heavy lines, is the part of the head on which lice were placed. Self-grooming by the mice was prevented with Elizabethan collars. The black areas are those in which lice were found 24 hr later.

their heads. After 24 hr the mice were killed and lice were found over the whole body (Fig. 8), thus indicating that they wander readily and rapidly from the fore- to the hindpart of the body.

V. Discussion

Self-grooming was carried out primarily by combing the hair with the lower incisors and thus was limited to the part of the body which could be reached by

the mouth. This was principally the hindpart of the mouse and, as a result, the distribution of the lice was restricted. All stages of the life cycle were found predominantly on the forepart of the body with the exception of the stage I nymph which was found over the whole body. When Elizabethan collars were fitted around the necks of mice to prevent self-grooming, their louse populations increased from less than 200 to over 1000 in 3–4 weeks and all stages were found on the hindpart of the body.

Lice moved readily and rapidly from the forepart of the body to the hindpart, and thus it was possible for grooming of the hindpart of the body to control the number in the forepart. More than half of the hindpart of the body, however, had to be groomed to control the number of lice.

Both the prevention and the reduction of the efficiency of grooming allowed the lice to spread over the body. Therefore, the presence of any stage of *P. serrata* in numbers on the hindpart of the body is evidence of a decrease in the efficiency of its removal by self-grooming. Thus the preponderance of stage I nymphs over the other nymphal and adult stages and, in particular, their abundance on the hindpart of the body indicates that they were not being removed efficiently by combing with the teeth, probably due to their small size.

The basic requirements, therefore, for grooming to control the number of lice on mice and probably other rodents are:

(1) The technique should be efficient. This may vary with the size of each stage of the life cycle of the louse.

(2) The time spent grooming should be sufficient.

(3) The area of the body groomed should be adequate.

(4) The lice should not have predilection sites and should wander readily and rapidly into the region which is groomed.

If any one of these requirements is adversely influenced the number of lice will increase. Should the influence of such a factor be relatively slight, the number of lice will increase but will still be controlled and their distribution will become less restricted. The nature of the factors which influence these requirements may vary greatly, as may be seen in the following discussion of previous observations on louse populations on other rodents.

Experiments have been carried out on the influence of deficiencies of vitamins A (Searls and Snyder 1939; Kartman 1942) and B_6 (György 1938; Holmes 1958) in the diet of rats, and the increase in the number of lice on the rats on these deficient diets has been taken as indicative of a direct relationship between vitamin deficiency and the size of the louse population. In all these experiments, the rats became listless and showed definite symptoms of a vitamin deficiency. In this state, as Buxton (1947) has suggested, rats probably spend less time grooming which could account equally for the increase in the number of lice. In the present experiments, the body weights and demeanour of mice fed on an adequate diet remained normal whilst their louse populations increased rapidly when the efficiency of grooming was deliberately impaired (Figs. 6 and 7), thus demonstrating that grooming is the primary factor controlling the number of lice on mice.

The distribution of lice on some of the wild rodents of the Volga Delta has been described by Dubinin (1953). On *Apodemus agrarius* (Pall.), *Arvicola terrestris* (L.), and *Micromys minutus* (Pall.) the lice were restricted to the head and shoulder-blade region, and on *Mus musculus* and *Microtus arvalis* to the head and the root of the tail. These parts of the body cannot be reached by the mouth or only with difficulty.

Vysotskaya (1950) studied the fluctuations of *Hoplopleura acanthopus* on *M. arvalis* and found that the number of lice increased during the latter part of winter and declined in the summer. The cause of the decline was the loss of lice with the winter coat as it was shed. She found also that they were confined to the forepart of the body in the autumn, and in winter to around the root of the tail also, but in the spring they were found all over the body. She attributed this to behavioural responses of *M. arvalis* to the surrounding atmospheric temperature, such as sleeping in a curled-up position in winter. A decrease in the efficiency of grooming offers an alternative explanation for both the increase in numbers and the change in the distribution of the lice. This could be due to the increased thickness of the winter coat reducing the efficiency of the grooming technique, to less time being spent grooming because of the increase in the foraging and breeding activity, or to other factors associated with the conditions of stress to which the voles are exposed at this time. The findings of Cook and Beer (1958) with infestations of *H. acanthopus* on the meadow vole *M. pennsylvanicus* could be explained similarly.

As rodents become larger than mice the surface area of the body which has to be groomed increases. It might be anticipated, therefore, that grooming as carried out by mice may fail eventually to control the number of lice on larger rodents unless the grooming technique is improved. However, should there be differences in the rapidity with which the various species of lice can multiply on large or on small rodents, a less efficient grooming technique may be adequate when the rate of multiplication of the louse is less. On the rat, *R. norvegicus*, the louse *Polyplax spinulosa* Burm. is dispersed over the dorsal and lateral aspects of both the fore- and hindpart of the body (Dubinin 1953; Holmes 1958), indicating a decrease in the efficiency of grooming with the mouth which, however, may be due to factors other than the greater surface area of the rat. The average number of *P. spinulosa* on rats was found to be about 400 by Holmes (1958) and 500–600 by Zakovich (1946) which is only 4–5 times greater than the average number on mice. Thus the densities of the louse populations on rats and mice do not appear to differ greatly which suggests that the number of lice on the rats is being controlled efficiently. The life cycle of *P. spinulosa* requires 3–4 weeks to complete (Holmes 1958) and consequently it is unlikely that *P. spinulosa* can multiply as rapidly as *P. serrata* whose life cycle requires only 2 weeks for completion. Thus self-grooming is probably the main factor controlling the number of *P. spinulosa* on the rat also, even though the technique is apparently less efficient. It may well be that the greater efficiency of self-grooming by the mouse has caused selection for lice with a shorter life cycle.

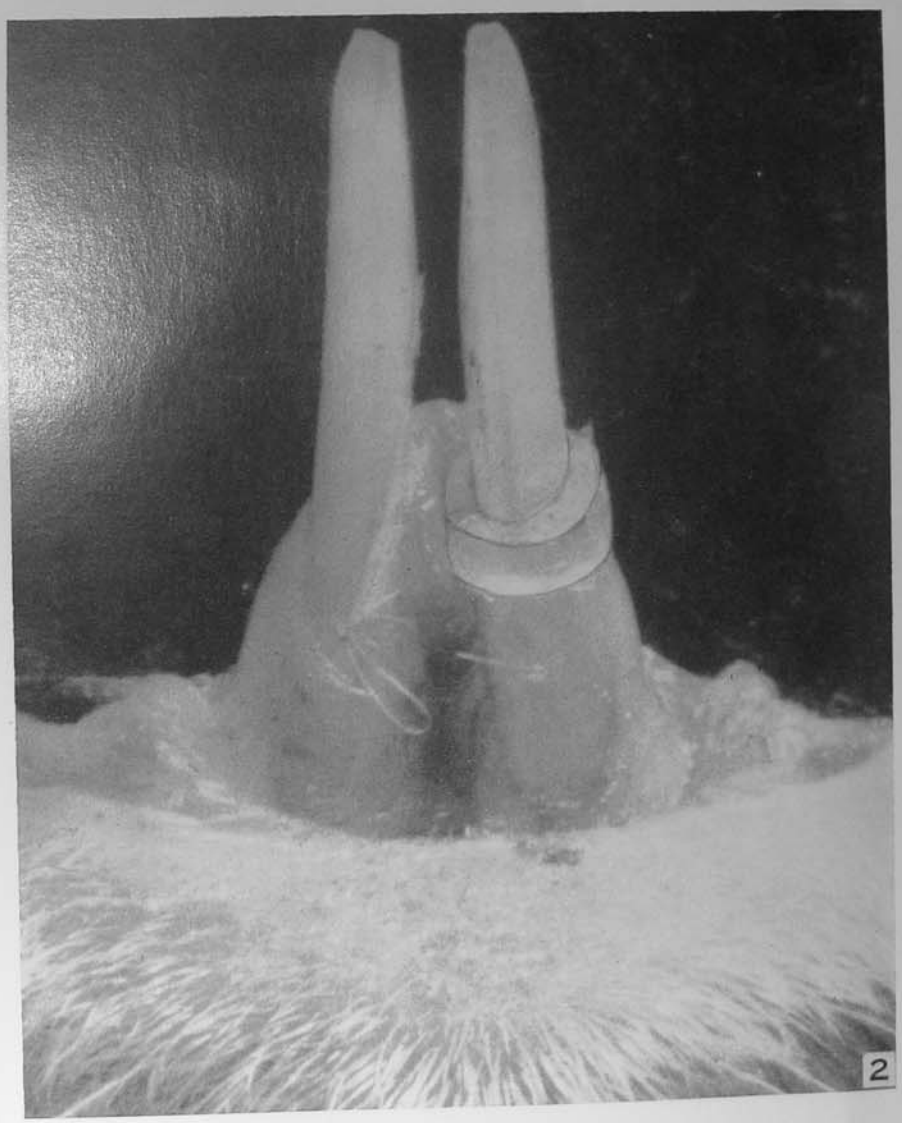

Fig. 1.—Elizabethan collar of copper wire placed around the neck of a mouse.
Fig. 2.—Ring of stout polythene tube placed around the left lower incisor of a mouse, wedging the lower incisors apart.

Self-grooming is the principal factor which controls the distribution and abundance of *P. serrata* on the mouse *Mus musculus*, and probably also of lice on other small rodents. Many diverse factors can influence its efficiency which may be expected to decrease as the size of the rodent increases. It is necessary, therefore, in any study of the factors which cause fluctuations in the number of lice on rodents to take the effect of self-grooming into account.

VI. Acknowledgments

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