

THE LIFE HISTORY AND BEHAVIOR OF THE EUROPEAN EARWIG, *FORFICULA AURICULARIA*, L. IN BRITISH COLUMBIA

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Introduction

The European earwig, *Forficula auricularia*, L., has been studied by previous investigators in British Columbia, but some features of its life history have not been made known. This paper fills many of the gaps, largely by the use of quantitative methods*.

Historical Background

The European earwig, *Forficula auricularia*, L., has become an extremely objectionable garden and household pest in Vancouver and nearby British Columbian cities. In order to check it, extensive control work has been carried out by the authorities. Upon this problem some local investigation was made in 1926 and 1927 by J. Stanley of the University of British Columbia. He studied life history, seasonal development, and control measures. However, the main basis of the control work has been the findings of B. B. Fulton of Portland, Oregon.

Outline of Investigations

In 1929, May to September inclusive, a further study of the earwig was undertaken in New Westminster, twelve miles from Vancouver. The research included studies on parasitism and mechanical control in addition to work done directly on the life history. The two former, although not included in this paper, contributed much incidental data. Further field notes were made and rearing was carried on during the winter 1930-31 to complement the material previously gathered in the summer.

FIELD OBSERVATION ON EARWIG HABITS

Trapping and rearing of the earwig, together with continuous observation of the life history, were carried on over a period of two years.

Winter Observations

Place of Hibernation

According to Fulton ('24) the earwig overwinters "under boards or stones on the ground or in cavities in the ground, an inch or two under the surface, rarely deeper." Although this statement is true for British Columbia, it was extremely difficult to find earwigs even in these situations in the winter. City blocks harboring earwigs by the tens of thousands in the summer have failed to yield one earwig in hours of searching during the winter. Other entomologists in British Columbia have had the same experience. Earth to a depth of two feet, matted old leaves, bases

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of trees, hollows in trees, upper parts of thick bushes, half buried planks, dry sheltered earth under verandas, and dry and wet piles of firewood, have been searched in vain. Occasional earwigs have been found in the decayed external layers of the bases of electric power poles exposed in the course of road work: also in one case an earwig was found in a buried piece of rubber tubing.

The only type of situation yielding earwigs in numbers has been steep banks. They occurred in considerable numbers under the small stones in a rockery forming a wall about four feet high bedded in stony soil. Similarly, earwigs were found at the top of a gravel cutting along a road. Both rockery and bank had a southern exposure. It was impossible to say what conditions governed the choice of these spots, since similar banks and parts of the same banks were unoccupied. It appeared in the latter case that the Isopods were much more numerous in those parts of the bank where no earwigs occurred. Possibly the determining factor was soil drainage. The earwigs were found in cavities in the earth against the stones.

Breeding in Winter

In the banks which did harbour earwigs, eggs were found quite early in the winter. The season of 1931 was unusually mild with very little frost, so that this reproductive activity may have been abnormal. At any rate, three out of nine females found in January 14 were tending eggs. Part of one of these clutches removed to the zoological laboratory hatched in nine days. Comparison of this period with the thirty-one days incubation required by eggs laid in the laboratory suggests that the field eggs had been laid for some time before being found. Females were found in various January collections to have laid eggs. Three females taken on February 14 were brooding eggs.

The possibility that the female earwigs were occupied with, or preparing for, oviposition during January and February, 1931, is substantiated by the fact that, while the males were wandering freely, the females were not. This idea was suggested when stones of the rockery which had been lifted January 17 were again searched February 3. Under the stones that had been previously raised to remove the earwigs, about forty-five males, but no females, were collected. This situation recurred on February 27, when thirty-six males and only one female were found under the same stones. Apparently the only females captured during this period were from situations previously undisturbed. It was further noticed on February 3, after several warm days, that a large number of earwigs, exclusively male, had moved out from the embankment under some creepers at the foot.

Spring and Summer Observation

A variety of observations, including oviposition, nesting, copulation and copulation behavior, were made during the spring and summer.

Second or Delayed Oviposition

In May and June, some overwintered adult females were wandering freely at a time when the majority of them was caring for brood. They occurred in the trees even more than on the ground, as was definitely proven in quantitative trapping, which would seem to indicate that they were in no way associated with nests. Dissection of thirty such earwigs during the last fortnight of May showed almost all to carry eggs at all

stages of development. This phenomenon suggests that a second or delayed brood occurs in the field. The fact that females can produce a second clutch of eggs was conclusively demonstrated.

From among the numerous females dug up on May 16, 1929, thirty-three, or about one-third of them, that were quite definitely tending brood, were selected. These were put in an enclosure that did not permit ingress or egress. No males were added. As described below, fungous disease was very serious among these overwintered adults so that most died. However, by June 7, six surviving females were found to have nests on the surface of the ground under pieces of wood. Of these, five had 41, 44, 45, 33 and 57 eggs, respectively, while one lot was not counted. Of these six females, two survived to hatch their eggs. This process was completed on June 26. On July 2, a third nest was found under the ground with the eggs not quite all hatched. These three surviving females and an overwintered male were put in a suitable jar to see whether they would produce a third brood. None was obtained, although all these females survived for a number of weeks, and one lived until the first week in October.

Earwigs Nesting Above Ground

In two cages used primarily for the study of parasitism, some earwigs were noticed to nest above ground, in contrast to their usual subterranean habit.* In these cages, which were six feet square, two lots of about 100 adult overwintered earwigs were confined. About sixty per cent. of the many clutches found were in the folds of newspapers, which were scattered about. This paper teemed with other adult earwigs, a condition which would not seem to favor egg laying. The remainder of the nests were on the surface of the ground, mainly below the paper. The soil could not be turned over to determine how many nests were below ground.

It is possible that this nesting above ground was due to the wet condition of the soil. In the case of ten females kept individually in glass quart jars, none laid in the available folds of paper and only one on the surface of the soil, while the rest oviposited below the surface. This soil was much drier than that in the large cages, although it was also less crowded.

A field occurrence of this modified nesting habit might be sought in city blocks having very wet soil even in the hot summer. Such a district lies about Trout Lake at the bottom of a drainage basin in Vancouver south. It is difficult to suppose that earwigs breed in the normal way, underground, in such a place. This region was found, in an inspection made in August, 1929, to be lightly infested with earwigs.

Period of Copulation

In the spring of 1929 a great many males were found to have overwintered. They were a sluggish group which died off rapidly, even compared with the companion females. Nevertheless, these males retained the capacity to fertilize the females until their end. In the stocks of earwigs maintained in the large cages, at least four definite cases of copulation were seen during the first fortnight in June. In stocks of earwigs maintained during the winter of 1931, copulation was found to occur at all times.

*See description of cages, p. 32.

Fungous Disease

In the large cages for study of parasitism the 2000 adult overwintered earwigs introduced in the spring practically all died before the new generation of individuals became adult. The most common cause of death appeared to be a fungous disease. This apparently did not attack nymphs to the same extent as the adults. It occurred mainly between the sclerites and between the abdominal segments, and in the nymphs where the body wall was thin. The probability that the fungus is more than saprophytic is suggested by the fact that earwigs are commonly seen moving about feebly with the first hyphae appearing. Death occurs about twelve hours later. The body after death is bloated and filled with mycelia. An identification of this fungus was not obtained, since no fruiting bodies could be found internally. Fruiting bodies of **Mucor**, which was probably secondary, were found plentifully on the surface.

So far as could be seen, this fungous disease occurred among earwigs when high relative humidity coincided with warmth. In the summer of 1929 it was found especially in the large parasitism cages where the soil became very wet in spite of all efforts to protect it from rain. Also, the disease was very much more severe during the winter among adults kept in the zoological greenhouse or in the laboratory than among the earwigs seen in the field. It was suggested that the susceptibility of the insects to disease under the preceding conditions was occasioned by a combination of wet conditions and relatively high temperature. This hypothesis was suggested by the fact that when the diseased lots of earwigs were put in an open window, where the winter draught could blow over the containers, the death rate declined greatly. This situation was never cold enough in 1931 to freeze the moisture in the tins. At the same time, some tins of earwigs, which had been kept on the ground beneath a house, had remained practically free from disease while there. Although the temperatures were moderately low in this situation, the earwigs were quite active, even engaging in oviposition. Upon removal of the tins to a room which went up to 70° F. for many hours a day, the fungous disease literally flared up.

Autumn Observations

During the autumn, not many observations were made on the life history of the earwig other than some which are discussed under the topic "Trend of Population."

Food Habits

The earwig is omnivorous, as many writers have reported. The common crucifer, **Sisymbrium officinale**, L., white clover, **Trifolium repens**, L., and dahlia, **Dahlia variabilis**, were found to be favorites, apparently in the order given. The adults in cages were found to eat the leaves of many plants, including those of dandelion, **Taraxacum officinale**, Weber, large leaved maple, **Acer macrophyllum**, Pursh, and hollyhock, **Althaea rosea**, Cav., if other food was not available. Much pollen was found, by dissections, to have been eaten. That of fruit trees early in the season, and of dahlias later, were eaten. The earwigs ate pulverized apple and also drained the druples of raspberries, when in captivity. Under this condition they were also found to eat boiled beef and liver, and fresh bread crumbs, upon which diet alone the earwigs thrived. As far as could be seen, there was no difference between the kinds of food eaten by nymphs and by adults, respectively.

Adult earwigs were collected at 3.30 a.m., May 20 and 23 in order to determine what they had eaten during the night. Eleven of these examined in detail contained **Pleurococcus**, in most cases in large quantities, as well as other food. Since this alga seems to occur in a simple lichen, the accompanying hyphae were sought. Apparently branched and unbranched filaments were present, although this observation was not confirmed by a botanist. Lichen containing **Pleurococcus** occurs almost universally on trees, poles, fences, etc., about New Westminster. The nature and importance of the arboreal habit of the earwig may perhaps be determined, after more extensive examinations of this sort, to be connected with the occurrence of lichen on the trees.

Two cases of cannibalism were seen in the field, while in the cages, earwigs killed with scalding water were eaten readily by the living. In the rearing experiments of the winter, the female earwigs ate a great many of their own eggs. This occurred in spite of the fact that plenty of food was present. In one particular case, a quiescent female, when disturbed, picked up an egg, drained it and then swallowed the skin.

Relationship Between Distribution of Earwigs and Density of Human Population

In the former municipality of South Vancouver, the degree of infestation by earwigs apparently varied directly with the degree of human occupation. The northwestern part of the district adjacent to the City of Vancouver, and a strip along the Kingsway highway are largely occupied by dwelling houses; the southern part, particularly in the east, is largely unoccupied. In the northwestern part the majority, and in the southern regions the minority, of the lots per block are heavily infested. While a relationship like that suggested here, has been generally assumed to exist, this data would make its quantitative demonstration and evaluation possible. Unfortunately, time has not been available to make this study possible.

REARING EXPERIMENTS

Rearing was carried on under modified outdoor conditions in 1929 and under laboratory conditions in the winter of 1930-31. This work was fairly successful. In the first case, about 50% of the young nymphs introduced into the cages, and in the second case 92% of the earwigs hatched, reached maturity.

Conditions and Procedure in Outdoor Rearing

In the course of an attempt to obtain parasitism of the earwig, in the summer of 1929, two large cages were set up. The first two thousand nymphs captured in 1929 were put in the two cages. In addition, a few nymphs were bred from adults which were placed in the cage at the beginning of the season. Although this experiment was not undertaken with the object of gaining data on the life history, some were obtained incidentally.

The earwigs were kept in an enclosure formed by setting twelve inch by one inch planks four inches into the soil with barriers on the upper edge to prevent the escape of earwigs. Each cage was six feet square. Walls and a roof of cheese-cloth were added for the purposes of the study of parasitism. Within these cages the air movement was naturally less than outside, and the temperature and relative humidity were higher. In order to keep the ground as dry as possible, the cages were covered with oil-cloth at night and during rains.

Conditions and Procedure in Laboratory Rearing

During the winter of 1930-31, eighty-nine earwigs were reared to maturity in the zoological laboratory. The eggs used were obtained from earwigs captured in September, 1930, in New Westminster. The males and females had been kept together during the autumn in cages and tins in the university greenhouse and in the zoological laboratory. The female, with her eggs, was isolated as soon as she began to lay. As soon as hatching was completed, the mothers were removed. The nymphs were kept under constant observation until they became adult.

Both the nests of eggs and the nymphs were kept in seamless tins, which were two and three-quarters inches in diameter and three-quarters of an inch deep, and provided with tight fitting lids. Since the earwigs were kept on damp towel paper, the air in the tins was always saturated with water vapour. A thermograph was kept beside the tins of developing earwigs. It is sufficient to say that the average room temperature was 62° F., with a general fluctuation of 3° F., and a maximum of 11° F.

The young during this winter were fed upon freshly mashed boiled beef liver, freshly crushed bread, and freshly mashed apple. At the time of hatching, sprouting wheat was added, and afterwards the leaves of dahlias. This additional part of the diet was probably unnecessary.

In order to reduce disease among the nymphs, the containers, food and paper were at first changed every day, then every two days, and finally every three days. Care was taken always to use cleaned tools for the different sets of earwigs.

Conclusions on Rearing

1. Length of Instars

The average duration of the various stages under the constant and presumably favorable conditions of the laboratory were:

Stage	Egg	Instar I	Instar II	Instar III	Instar IV
Days duration	31	14	14	13	19

The method employed in calculating the average duration of the stadia is to find the periods between the median days of the various periods of metamorphosis. Thus, the day on which 50% of the moults from first instar to second instar had been completed marks the lower limit of the duration of the second instar, and the date on which 50% of the moults from the second to the third instar had been cast determines the other limit of the second instar. The average period thus determined is fourteen days. Similarly, by a determination of the median day for succeeding periods of ecdysis the average duration of the succeeding stadia are determined. By an obvious extension of this principle, the average duration of the egg state and first instar are calculated.

In Figure I the actual numbers of moults per day is shown together with the median days of laying and hatching. However, the representation of the appearance of adults is modified to show the appearance of males and females separately. The earwigs are subdivided into three lots. Lots I and II each consist of the young from one clutch. Lot III consists of the young from two clutches laid concurrently. As can be seen from this chart, there was remarkably little variation in average

length of the stages from the three lots. This agreement makes the calculation of average duration of instars shown above very reliable.

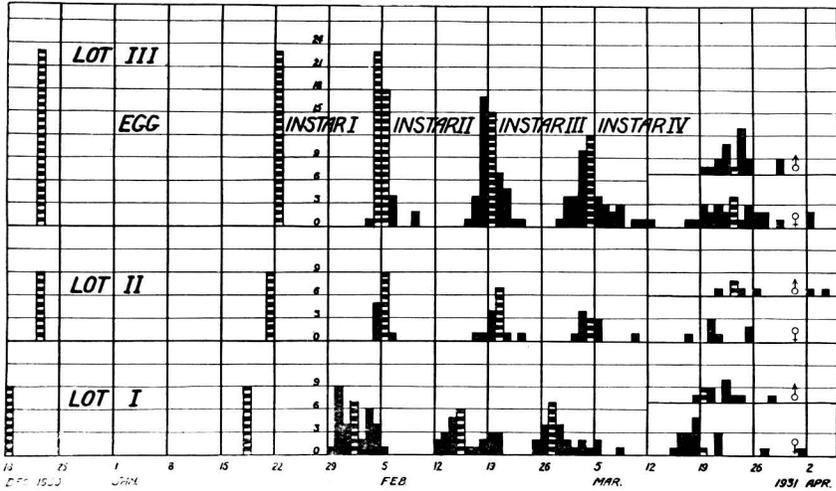


FIGURE I

Data on Rearing Earwigs

The number of moults cast daily is shown by solid black columns and the median day of each period of ecdysis is shown by striated column. The number of moults cast each day in the various groups is indicated by the height of the columns. One division represents three moults.

2. Statistical Scatter in the Period of Metamorphosis

The scatter of the period of metamorphosis increased greatly as the earwigs developed, even under the constant conditions to which they were subjected in the laboratory. The standard deviation of the length of periods of ecdysis from lot III measures this tendency as shown:

Moult	I	II	III	IV
—in days	$1.11 \pm .07$	$1.35 \pm .09$	$2.58 \pm .18$	$3.48 \pm .24$

This increase in scatter, indicated by these figures, can be seen in Figure I.

3. Chronological Appearance of Adults by Sexes

The females became adult a day or so earlier than the males.

4. Proportion of Sexes

Among the eighty-nine earwigs reared in the laboratory, fifty-two were female and thirty-seven were male. Thus $41.6\% \pm 3.6\%$ of the population was male. The formula used is $PE = .6745 \sqrt{\frac{p \cdot q}{N}}$ when in this case p = number of males; q = number of females; and $N = p + q$. By the same formula, the probable error of an expected 1/1 ratio between the

two sexes in a total population of eighty-nine would be 3.2 earwigs. Therefore, the deviation of the experimentally obtained ratio of 7.5 earwigs from a 1/1 ratio has a probable error of ± 4.6 earwigs. That is, there is one chance in four that the experimental ratio deviated as it did from a 1/1 ratio, by chance. However, outdoor rearing gives additional support to the supposition that males form less than half the adult population. Of 1181 adults reared from nymphs captured in June, 1929, 45.5% \pm 1.5% were male. The difference between this latter ratio and that from indoor rearing is 3.9% \pm 4.2%.

5. Dimorphism in Males

Male earwigs exist in two non-intergrading groups—those with short and those with long cerci. It had been originally expected to observe the proportions in which the two forms appeared and to see whether they matured simultaneously. However, all the thirty-seven males obtained had short cerci.

QUANTITATIVE STUDY OF EARWIG POPULATION IN THE FIELD —THE TREND OF POPULATION

The life history of the earwig throughout one summer is described below from a quantitative view-point. The main gauge used is the number of earwigs caught in a large number of widely separated traps. Results of other experiments, particularly rearing, are used to support the trapping observations. Apart from the biological interest of the material, it is of the highest value economically as a basis of control work.

Procedure in Trapping Earwigs

Extensive trapping was carried on in the months May to September, inclusive, 1929. One hundred and ten traps of various sorts were set out on eleven lots lining the periphery of a square mile of the hill on which New Westminster is built. The traps were scattered so that the results obtained might be as general as possible.

Of the eleven city lots used for trapping, eight were well-kept gardens, one was a deserted garden, one a small orchard, and two were unimproved lots covered with bush and grass. On eight lots, referred to as "trapped lots", the earwigs were destroyed as captured, and on three lots, referred to as "control lots", the insects were returned to the ground near the trap after the count had been made.

Traps Used

The traps used in the collection were very simple. They fell into three groups, according to their position; those in trees, those on stakes, and those on the ground.

The tree traps, which were five feet above the ground, consisted of:

1. Jute sacking bundled up in the crotches of trees;
2. Jute sacking around the trunks of trees;
3. Newspaper bundled up in the crotches of trees.

The traps which were eight inches above ground on stakes consisted of:

4. Inverted flower pots filled with grass;
5. Inverted tin cans filled with newspaper.

The traps on the ground consisted of:

6. Old dry dahlia stems;
7. Sections of bamboo, node and internode.

Collection Period

During the first three months of trapping, May, June and July, collections were made nearly every day from some of the traps in each group. A total of about 1200 visits a month were made to the one hundred and ten traps, and an average of 13,000 earwigs taken per month. Only a selected group of traps, those in which the greatest numbers of earwigs were caught, could be maintained over August and September. During this period, three hundred and forty visits a month were made to thirty-four traps and an average of 2500 earwigs taken per month. Some further trapping was done by a helper in the late autumn of 1929 and early spring of 1930. A little parallel trapping was carried on in Vancouver, twelve miles away, concurrently with that of New Westminster. The earwigs were seen to be behaving similarly in the two places.

Arithmetical Deviation of Life History Chart

Figures II and III show the trend of population. The average catch for one trap for one collection is depicted for each day on which collections were made. The catch from the "trapped lots" is more extensive than that for the "control lots", so is used in the life history charts which follow. In describing the derivation of the charts, that for the tree traps is first considered.

The total catch of nymphs and adults per average trap per day is calculated for the whole season from the select group of tree traps visited continuously throughout the five months. This was the five tree traps that caught the most earwigs in the first three months of trapping. The median yield for the first month per collection for the group was twenty-two earwigs, and for the remaining four months sixty-nine earwigs. A five day moving median is used to give the averaged, daily, total catch throughout the season. The median is used, since it is influenced less by extreme, abnormal catches than other possible measures of central tendency. Moreover, it shows the turning points and termination points of a curve or histogram clearly and accurately.

The percentage composition of the daily catch in adult males, adult females, and various nymphal stages, is determined independently of the averaged total catch per trap, previously determined. It is based upon the catches from all tree traps visited on each day. In the course of the season, thirty tree traps were operated, some for short and some for long periods. Thus the composition of the catch might be based upon all thirty traps on one day and on twenty-one traps the next day. In all events a great many earwigs were collected. These daily collections are smoothed with a three day moving-arithmetic mean, largely to reduce fluctuations in catch which were caused by weather disturbances. Projection of these percentages into the averaged total daily catch per trap, as already determined, gives Figure II.

The percentages for the whole period are based upon about 20,000 earwigs. In the course of the five months 12,786 dead nymphs from the ground, stake and tree traps, collected over forty-six different days, were identified as to instar by a binocular examination. For the first part of the season, the earwigs examined included the total catch of nymphs; later only a sample was taken as a check on the field determination. The field determination has been used, for the most part, as the data for the calculations.

For determining the general level of population, which changes fairly slowly, the five day smoothing period is desirable. It includes enough individuals to be reliable and extends far enough to smooth out short period variations in catch occasioned by weather. Moreover, the figures throughout the entire five months should be comparable, since they are based upon exactly the same traps.

In determining the relative abundance of the various groups of nymphs and adults, particularly of the former, since the numbers present change quite rapidly, the short period, three day, smoothing is desirable. The number of traps used or their relative effectiveness individually should not affect the ratios of the various groups in the total catch, since the various groups should occur equally in all like traps. However, since any one group forms but a fraction of the total catch, the percentages have been based upon a maximum number of traps, that is, a maximum catch. In this way the degree of reliability of the percentages obtained has been raised.

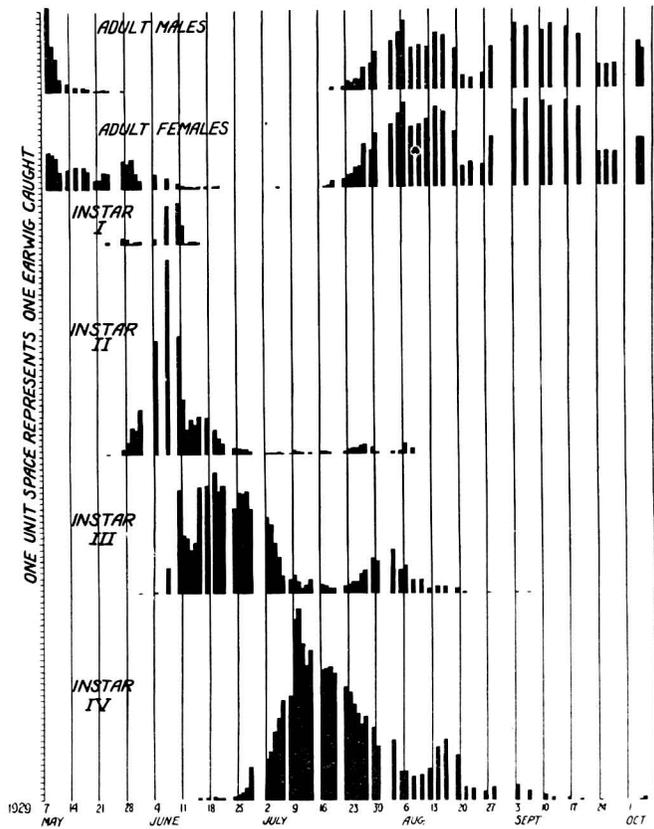


FIGURE II

Averaged daily catch of earwigs per trap for tree traps, five feet above ground. The total catch is resolved into component parts on nymphs according to instar and adults according to sex.

NOTE:--The actual number of earwigs caught is of little significance, since it depends upon the choice of traps. The fluctuations of the component groups are significant.

For the traps on stakes the procedure in plotting catches over the five months is identical with that described above for tree traps. Seven traps were maintained continuously over the period. The median yield per trap per collection during the first month was eight earwigs, and during the remaining four months, twenty-four earwigs. Eighty different traps were operated at different times during the season. The percentages of component groups are based upon 20,000 earwigs.

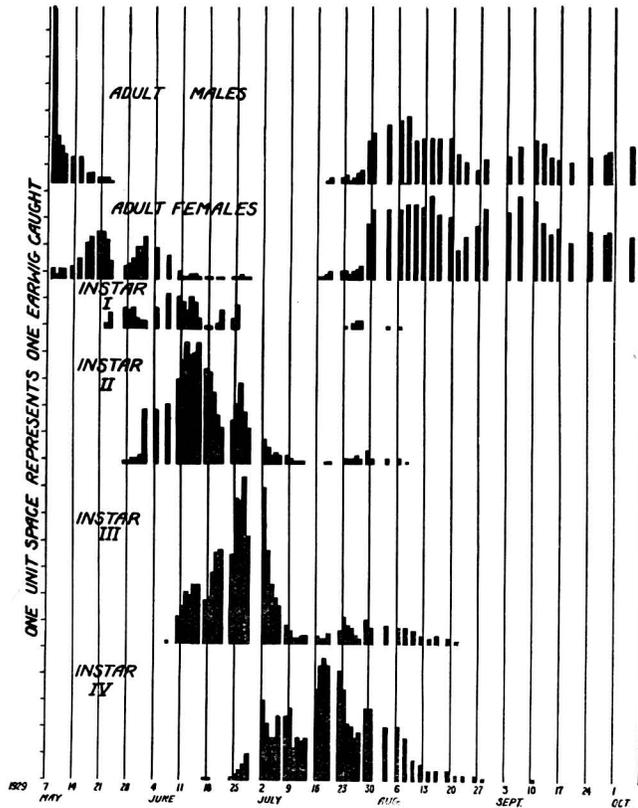


FIGURE III

Averaged daily catch of earwigs per trap from traps on stakes, eight inches above ground. The total catch is resolved into component parts of nymphs according to instar, and adults according to sex.

NOTE:—The actual number of earwigs caught is of little significance, since it depends upon the choice of the traps. The fluctuations of the component groups are significant.

Conclusions with Regard to Seasonal Behavior Made on the Basis Quantitative Studies

1. Survival of Males in Spring

In 1929 adult males were a significant fraction in the population until the third week in May, and a non-significant fraction all summer. In Rhode Island almost all male earwigs and apparently the majority of females (Jones '17) die during the winter. The differences in survival of adults in these two places for these two years suggests the lower

winter temperatures of the eastern coast may be important in controlling the earwig. In the west, as pointed out in the preceding discussion of disease, it is possible that the wet, warm conditions of the spring are responsible for most of the deaths occurring among the overwintered adults.

2. Females Without Brood in Spring

At the beginning of May, a portion of the adult female earwig population, in contrast with the majority, were by no means restricted to the ground with their brood. On the contrary, they occurred more freely in the tree traps than in the ground traps. This activity demonstrates clearly that these females were not in any way occupied with caring for brood.

The female catch became very much reduced in the fourth week of trapping. This was not primarily a result of trapping, since other groups, particularly the autumnal adults, showed no marked tendency to disappear from trapped lots. The decline in numbers of these vernal adult females may have been due to the fact that they had died, or to the fact that they were tending delayed brood or second brood; and therefore, not entering the traps.

3. Proportion of Males in Population

Among the adult earwigs obtained by trapping in British Columbia, the proportion in which males occurred agrees with that found in a similar way by H. H. Brindley ('12) in England. Collections made from the middle of July until the beginning of October, 1929 are compared with English collections made during August and September (with a little work in October) during the years 1892-1911. For New Westminster, the catch from traps on stakes was 37.9% male, from tree traps 42.1% male. In twenty-four English situations males formed less than half the population and in five, more than half. The median proportion was 38.9% male.

The proportions of sexes obtaining among earwigs reared from eggs to the imaginal stage is very close to the proportions caught in the field, i.e. $45.3\% \pm 1.5\%$ and $41.6\% \pm 3.6\%$ male, respectively. Of course, field catches are a reflection not only of these relative proportions of the two sexes, but also of differences in their activity.

4. Chronological Appearance of Adults by Sexes

In the field, as in the winter rearing experiments, the female earwigs were observed to reach maturity two days, on the average before the males. This is apparent from Figures II and III.

5. Second Brood or Delayed Brood

During the years the earwigs were studied, young seemed to occur at practically all seasons. As previously stated, eggs were found outdoors on January 14, 1931. On the other hand, nymphs were taken in traps on November 10, 1929.

Not only were nymphs present at other times than on the occasion of their main appearance in June, but they also showed a second similar period of abundance early in August. Nymphs of the first instar, which had not occurred in significant numbers since June 25 in ground traps, were again found there after July 23. This is shown in Figure III. The catch of second, third and fourth instar nymphs in tree traps rose successively after periods of steady decline on July 23, July 23, and August 13, respectively. This is shown in Figure II.

By way of analyzing the nature of the distribution of numbers of nymphs, the modes of the first and second periods of abundance from trees and ground (Figures II and III) were chosen by sight. These data have been replotted in Figure IV.

- a. The distribution of the modes for the various instars against time is of similar arrangement for first and second periods. However, the intervening time in the second period is uniformly shorter. This would be expected later in the season when development would presumably be more rapid.
- b. The interval between the modes for the second and third instars is shorter than that between the modes for the third and fourth instars. This evidence, that the third instar is of shorter duration than the fourth, agrees with evidence obtained in breeding, when the periods were thirteen and nineteen days, respectively.
- c. An apparent discrepancy exists in that the modes for the first and second instars fall on the same day for the first period of abundance and within half a day for the second period. Also, as is shown in a subsequent discussion, a further discrepancy arises in that, although nymphs of the second instar climbed fairly freely and were, therefore, presumably moderately active, very few of them were taken in traps. For the other instars, the numbers taken in traps and the relative activity are closely correlated. In view of these irregularities, it is suggested that the first instar behaves far less uniformly than subsequent stages, and that the data obtained really deal only with nymphs of the last few days before their first ecdysis.

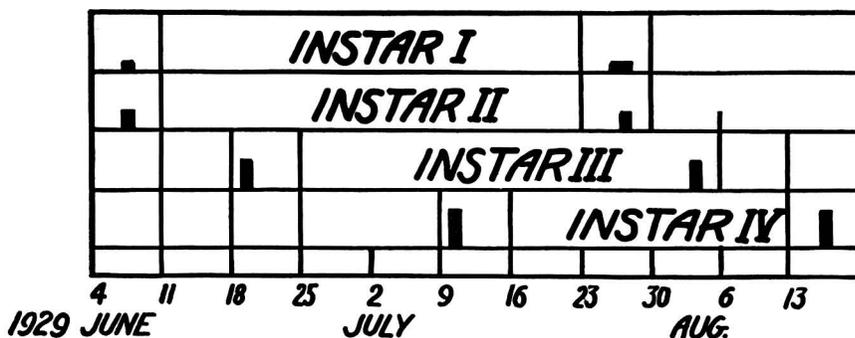


FIGURE IV

Modes of First and Second Broods for Each Instar

The modes for the first instar are taken from traps on stakes and for the remaining instars from tree traps.

Evidence previously presented in this paper for the existence of a second or delayed brood is summarized below. In the first place, a large group of females was not at all engaged in reproduction in May, when the majority of the females had brood. Possibly this group oviposited later, since the majority contained well developed eggs in May. In the second place, it was demonstrated that females deprived of their eggs on May 16 produced second clutches by June 7.

6. Comparison of Activity of Different Groups

A measure of the relative activity of nymphs of different instars may be obtained from a comparison of the respective numbers caught in tree traps. In the following table the numbers which were caught in each instar are compared with the number in the first instar:

Instar I	Instar II	Instar III	Instar IV
1.0	6.9	11.5	16.1

However, as can be readily seen, there are two ways in which these indices are subject to error. In the first place, deaths must occur in each instar, so that of the original population hatched a smaller percentage must survive into each subsequent instar. This phenomenon would tend to reduce the index for the older stadia. In the second place, while the first three instars take about the same time to develop, the fourth instar has a period 19/14 times as long, as was shown previously in discussion of rearing experiments and of trapping. Therefore, it would occur more frequently in traps than the earlier instars.

The preceding difficulties may be overcome by comparing the number of earwigs of any one group caught in the tree traps and traps on stakes, respectively. Moreover, this procedure makes it possible to compare the activity of the adults for the whole period or for any portion of their period, with the nymphs. A comparison is made below of the number of times more numerous the catch was for average tree traps than for average ground traps:

Vernal adult females	Vernal adult males	First instar nymphs	Second instar nymphs	Third instar nymphs	Fourth instar nymphs	Autumnal adult females	Autumnal adult males
3.2	2.1	1.9	3.9	5.1	5.8	4.6	5.5

It should be pointed out that the value of these indices lies largely in comparison with one another. The figures for the first instar are not typical because, as was shown in connection with Figure IV, probably only a small group of the oldest nymphs are represented.

The conclusions of the two preceding tables may be summarized as follows: The nymphs of the second instar are half as prone to climb as the third and fourth instars. The overwintered males are very inactive even in contrast with the companion females.

7. Heights Above Ground at Which Nymphs Occur Throughout the Season

In concluding the discussion on the behavior of the earwig, a general statement may be made on the extent to which earwig nymphs, considering all instars as a single group, climb. Figure V pictures the catch of immature earwigs from traps on the ground; traps on stakes, eight inches above the ground; and traps in trees, five feet above the ground.

The data for the five foot traps, or tree traps, is the same as that used for Figure II. The catch in each of the four nymphal instars is totaled and the results plotted as a curve. This curve is smoothed with an eleven day moving median. The data used in constructing Figure III

is treated in a similar way to draw up the curve for the eight inch traps, or traps on stakes. In addition to this data, which has previously been presented in a different form, further material not appearing before is used to give the average catch for the traps on the level of the ground, "0 inches". The traps used were old, dry dahlia stems and sections of bamboo. Since it is practically impossible to compare the catch from one type of trap with that from another, the total area included in each of the curves is made the same. The slopes, but not the heights, of the curves are significant and comparable.

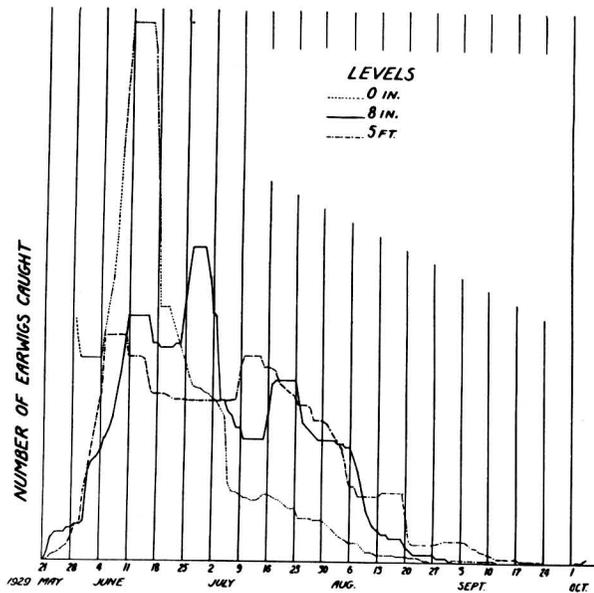


FIGURE V

Total Catch of Nymphs from Traps at Three Levels

From Figure V it can be seen that after about June 14, when the first instar predominated, the earwigs climbed with increasing freedom. The later instars did not go into the traps on the ground to any extent. On the other hand, they did not show any marked preference between the eight inch level and the five foot level, at any rate, not before August 10. The number of earwigs occurring at the eight inch level and five foot level apparently varied inversely with regard to minor fluctuations in population.

SUMMARY OF CONCLUSIONS

Nymphs were continuously present in the field from the beginning of May until the end of November in 1929. Two periods of abundance occurred with their maxima in the middle of June and the end of July. In the field the fourth instar required 1.8 times as long as the third to complete its development. In the second period of abundance the stadia were only .6 as long as in the first. In rearing under constant conditions, the nymphal stadia were 14, 14, 13 and 19 days respectively. In both rearing and field work females became adult a day or so earlier than the males. The latter only formed 40 per cent. of the population in the autumn.

On January 14, 1931, females were found with eggs, one clutch of which appeared to be at least half way hatched when removed to the laboratory. Females removed from their eggs in May laid second lots of from 41-57 eggs. Other females, that were climbing freely when the majority were tending brood, contained well developed eggs. Taken all together the evidence suggests that a considerable number of eggs was laid, after the main period of reproduction in the early spring.

Earwigs were only found during the winter on stony banks. Males die off earlier in the spring than females, although they apparently overwinter to about the same extent. From concurrent behavior in outdoor cages and a few observations of dead earwigs, fungous disease was responsible for their deaths. In winter work this disease occurred among adults brought from temperatures near 40° F. to about 65° F., or slightly higher.

Quantitative expressions of the relative activity of different groups of earwigs were obtained by a comparison of numbers of each group occurring in accessible traps with numbers in less accessible traps. Nymphs of the first instar appeared only at the end of their stadium above the ground. The second instar and vernal adults climbed freely. The third and fourth instars climbed about twice as readily. In the spring females were more active than males, while in the autumn males were the more active.

The correlation between density of human population and earwig infestation was demonstrated in a detailed survey of South Vancouver.

A limited number of earwigs which were dissected were found to have eaten **Pleurococcus**.

Earwigs nested freely above ground in paper, under the artificial conditions of the outdoor cages.

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