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THE NATURAL CONTROL OF *HETEROCAMPA* *GUTTIVITTA*¹

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In the April issue of the Journal, page 16, appeared an article by Mr. Burgess concerning the abundance of *Calosoma frigidum* in New Hampshire during the previous summer. Data were given showing that in areas where the beetle larvæ had finished feeding 78 per cent. of the pupæ of *Heterocampa guttivitta* had been destroyed, and where the larvæ were about one-half grown 54 per cent. of the pupæ of this moth had been killed at the time of the last examination, August 21-25, 1909. In view of these facts it seemed desirable to continue the observations this summer, in order to determine whether the work of this beneficial beetle, or of any parasitic insects, might be bringing about the natural control of *Heterocampa*. Accordingly, it was planned to make several trips to the region visited last year in the vicinity of North Conway. Mr. Harry S. Smith spent from July 10 to July 13 in this section making observations and collections on Mount Kearsarge, White Horse Cliff and various other ranges in the vicinity. Localities were visited where the trees had been very slightly to completely denuded by the caterpillars during the previous year, but Mr. Smith was able to find only an occasional larva of *Heterocampa* and very few specimens of *Calosoma frigidum*.

An examination of the earth showed that a very large percentage of the *Heterocampa* pupæ had been eaten by *Calosoma*, and that only a few moths had emerged in a normal manner. In spite of this, however, numerous eggs of the moth were found deposited singly on the leaves of beech and other trees. Mr. Smith noticed that most of these

¹ Occasional contribution from the Gypsy Moth Parasite Laboratory No. VI.

eggs had apparently hatched, but, on more careful examination he found that nearly every one had been attacked by a minute egg parasite. In a beech grove on the southern slope of Mount Kearsarge a count of 56 eggs of *Heterocampa* gave the following results:

Number containing prepupæ of parasite	35
Number from which parasites had emerged	14
Number from which caterpillars had hatched	2
Number of eggs apparently dead	5

This shows that the percentage of parasitism in this case equaled 87.5. Only one pupa was found in each parasitized egg, and no larvæ of the parasites were observed. This was probably due to the fact that the observations were made a little too late in the season to secure the early stages of the egg parasite.

Mr. Smith brought specimens to the laboratory at Melrose Highlands from which were reared a considerable number of egg parasites. Examples have been submitted to Mr. C. T. Brues of the Bussey Institution of Harvard University, who has identified them as very similar, if not identical, with *Telenomus graptæ* Howard.

On July 24 Mr. Fiske, accompanied by Mr. Reginald Wooldridge, of this laboratory, visited the region near White Horse Cliff where observations were made by Mr. Smith about two weeks previous. No caterpillars or beetles were found and conditions were much the same as those reported by Mr. Smith. Evidence of the work which had been done the previous year by *Calosoma* was very easy to obtain, and eggs of *Heterocampa* which had been parasitized by *Telenomus* were present on the foliage. Out of eighty eggs examined by Mr. Fiske, not one was found from which a parasite had not emerged, or in which a dead larva or pupa of a parasite was not present. Not one of the eggs had hatched and not a single caterpillar in any stage was observed.

Mr. Wooldridge continued his investigations at North Conway, West Ossipee, and Crawford Notch, but found very few *Heterocampa* larvæ, and only an occasional beetle. At Mount Cramer, North Conway, an examination of 29 eggs showed that 23 had contained parasites, and on Mount Kearsarge 29 eggs out of 33 examined in one locality, and 14 out of 16 examined in another had been destroyed by *Telenomus*.

In order to secure any further data that might be obtained a final examination of this territory was made by Mr. Burgess and Mr. C. W. Collins. The region which was badly infested near White Horse Cliff during the previous year was visited August 20. No evidence of the feeding of *Heterocampa* could be noted, but many of the trees showed

injury from the serious defoliation sustained the previous year. Examinations of the fallen leaves were made in order to determine the percentage of *Heterocampa* larvæ that had been destroyed the previous season, as well as to find out the average number of moths that emerged successfully. Mr. Collins continued the work and visited several localities near North Conway, Intervale, and Tamworth where the caterpillars had been abundant during the previous year, making counts of the pupæ found in badly infested areas and in sections nearby. The following table gives the summary of the counts made by him in the different localities and shows the number of pupæ destroyed by different natural enemies, as well as the number of moths which emerged in a normal manner. Twenty-seven out of 28 eggs examined by Mr. Collins were found to have been destroyed by *Telenomus*.

WORK OF HETEROCAMPA ENEMIES.

Areas examined.	Square feet.	Locality.	Pupæ Destroyed		Pupæ dead.	Moths emerged.
			by <i>Calosoma</i>	by parasites		
13	28	White Horse Cliff	62	...	...	2
10	19	Mount Kearsarge	35	2	...	6
5	13	Mount Hurricane	19	...	...	5
16	26	Mount Surprise	106	...	2	17
8	16	Tamworth, N. H.	15	...	2	1
11	19	Tamworth, N. H.	75	...	7	3
63	120		312	2	11	34

By computing the totals in this table it will be found that 87 per cent. of the *Heterocampa* pupæ in the region were destroyed by the larvæ of *frigidum* during August, 1909, which is slightly higher than the figures secured last summer, and 3.66 per cent. died from the attack of parasites or from other causes. The small percentage of moths—9.33—which emerged during the spring would undoubtedly have caused some injury to the foliage had it not been for the intervention of the tiny egg parasite already mentioned, although it is fair to assume that the caterpillars would have been seriously decimated by the swarm of *frigidum* beetles which must have developed from the large number of larvæ of the previous year. If we assume that the sexes of the moths were evenly divided, it is apparent that on the average only one female was developed from 21 pupæ of the previous year. This enormous reduction which was caused by the work of *Calosoma* is, of course, of great importance, still it must be remembered that each *Heterocampa* female is capable of depositing 500 or more eggs according to observations made by Miss Patch on this insect in Maine. It, therefore, is clear that the primary factor in bringing *Heterocampa* under natural control, aside from the work of *Calosoma frigidum* was due to the little egg parasite.

The observations made failed to show that Tachinid parasites played any important part in checking *Heterocampa*. A single caterpillar was found in 1909 which contained a large number of small maggots of an unknown species. This is the only instance where Tachinid parasitism was noted. Owing to the careful examination of a considerable area of leaves and soil it is inconceivable that the puparia of parasitic flies could have been overlooked if they had occurred in any great abundance.

Hymenopterous parasites on the immature caterpillars appeared to be lacking; or nearly so. None were found directly associated with *Heterocampa*, but cocoons of *Limnerium* similar to, and perhaps the same as the species which has been determined as *Limnerium clisiocampæ* Ashmead, were found in small numbers on abundantly infested trees in 1909. *Pimpla pedalis* and *Ichneumon* sp. were sufficiently abundant as parasites on pupæ in 1909 to cause considerable mortality, but since the pupæ were particularly liable to destruction by the larvæ of *Calosoma*, the parasites in turn suffered to a great extent and their utility was materially reduced.

The same scarcity of *Heterocampa* which obtained in New Hampshire this summer was also noted in Maine. During 1909 this insect was abundant to a greater or less extent throughout southwestern Maine. Practically all of the towns west of Boothbay, Augusta, Winslow, Clinton, Skowhegan and south of Madison, Stark, Farmington, and Bethel were infested to a greater or less extent and in many sections large areas were completely defoliated.

On August 13 Mr. Burgess visited a number of towns in the southwestern part of the state, but not a single larva of *Heterocampa* was seen and although diligent inquiry was made of many persons who travel to a greater or less extent over the territory which was infested the previous year, not a single instance could be found to indicate that *Heterocampa* was at all abundant or that any trees had been stripped by it this summer. In company with Capt. E. E. Philbrook and Mr. E. M. Sadler a visit was made to Mount Agamenticus, and during this trip a region was passed through which had been defoliated by *Heterocampa* in the summer of 1909. The trees showed no evidence of feeding by this species, although some of the oaks had been eaten by other caterpillars. Mr. A. M. G. Soule, one of the gypsy moth inspectors of the Maine Department of Agriculture, stated that he had seen a few *Heterocampa* larvæ in the region near Mount Agamenticus this summer, but not in sufficient numbers to do any damage or cause defoliation. He reported *Calosoma frigidum* as abundant last year and as occurring in larger numbers this summer.

A question which naturally arises is what has become of the large

numbers of beetles which were developed from the unusual abundance of larvæ in 1909. It is probable that in New Hampshire these beetles migrated to localities where other food was available and undoubtedly many of the native caterpillars which occur every year in greater or less numbers were destroyed by them. The investigations at the gypsy moth parasite laboratory have shown that beetles of this genus are able to survive for a long time without food and that in case the food supply is scanty only a small number of eggs are laid. This probably indicates what has happened in the *Heterocampa* regions in New Hampshire, so that on account of the relative scarcity of the food supply it is probable that the reproduction of this beneficial species has been greatly curtailed. Interesting information in this respect has been secured from the men engaged in the gypsy moth work in Maine. Capt. Philbrook states that during the summer his men continually reported large numbers of *Calosoma frigidum* in sections infested with the gypsy and brown-tail moths. The species had been found in previous years, but only in limited numbers compared with this year and it is apparent that many had migrated from the *Heterocampa* infested region in search of food. Mr. Soule states that on the Chase lot near the foot of Mount Agamenticus about three *frigidum* beetles were found under each burlap while on the Fitzgerald lot nearby the species was even more abundant. In several instances this beetle has become so abundant in southwestern Maine during the past summer as to cause complaint or inquiry by citizens. During June one of the summer residents at Cape Elizabeth, Me. sent to the laboratory specimens of this insect and a statement that they were found crawling on his grounds, trees and buildings in large numbers and were causing some alarm among the residents owing to the belief that they might be of a poisonous nature. Early in July a letter was received from Miss Harriet S. Gilbert from Prout's Neck, Me., together with a specimen of the beetle. In it she states that "for the past three weeks they have been all over our house, inside and out," and asked if they were beneficial or injurious, and if the latter what measures should be taken to destroy them. The last two instances show that there has been an enormous increase in this species in southwestern Maine, and probably a general migration from *Heterocampa* districts to gypsy and brown-tail moth regions, as it has been observed that this species is capable of flight, although no accurate data are at hand to show the distance to which they may be dispersed in this way.

From the habits and life history of *Calosoma frigidum* and *Telenomus graptæ* it appears that they are admirably suited as a natural means of controlling *Heterocampa*. What conditions could have brought

about the remarkable increase of the latter species during the past few years is difficult to conjecture, but there can be no question of the effective manner in which they have supplemented each other's work and reduced the numbers of *Heterocampa* to a minimum. This same principle, namely, the sequence of natural enemies working together in harmony on different stages of the host is what is hoped may be the final result of the introduction of parasites and natural enemies of the gypsy and brown-tail moths which is now being attempted in Massachusetts.

FUMIGATION BOX MATERIALS

By W. E. HINDS, *Entomologist to Alabama Experiment Station*

In connection with investigations relating to fumigation, the writer, assisted by Mr. W. F. Turner, has had occasion to test a variety of materials such as are commonly used in fumigation boxes or tents, to determine their comparative resistance to the transmission of air. The economic entomologist is frequently called upon to recommend materials and types of construction for fumigation outfits. This paper is offered in the hope that the experiments reported may be valuable for their suggestions in this direction. Naturally the material with which fumigation treatment is to be made is one of the first factors to be considered.

Our work thus far has been principally with carbon di-sulfid and with this substance, the problem of constructing a gas-tight container is complicated especially by its chemical properties. One volume of carbon di-sulfid liquid is supposed to produce 375 volumes of vapor. Naturally therefore, in a closed container, the pressure of gas from the evaporating liquid is a considerable factor. In an experiment to determine the amount of this pressure, a two-necked Wolff bottle was used as the container. In one opening a mercury manometer was tightly fitted through a rubber stopper. Through the other neck, a small quantity of liquid carbon di-sulfid was introduced and the opening then closed tightly with a rubber stopper coated with glycerine. In this tight apparatus, the pressure produced by the evaporation of the liquid at a room temperature of 60 degrees F., amounted in a few minutes to more than 2.5 pounds per square inch, or more than .15 of an atmosphere. At higher temperatures, the pressure would be very much greater than this. In all ordinary fumigation chambers, the leakage has been found to be so great that the evaporation of liquid carbon di-sulfid produces no increase of pressure even with a