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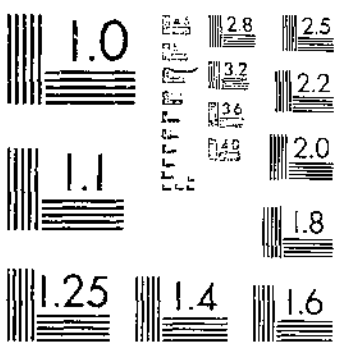

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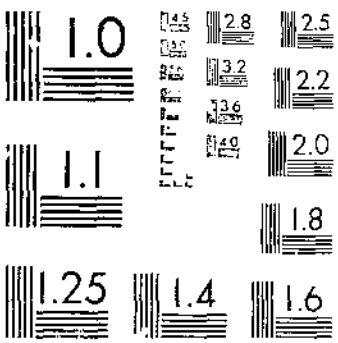

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TECHNICAL BULLETIN No. 366 JULY 1933

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D.C.

FURTHER INVESTIGATIONS OF THE PARASITES OF POPILLIA JAPONICA IN THE FAR EAST

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CONTENTS

INTRODUCTION

In a previous publication (*6*) [2] an account was given of the investigations on *Popillia japonica* Newm. and its natural enemies in Japan and Chosen (Korea) during the years 1920–1923, inclusive. The present account covers the work of the following 5-year period (1924–1928, inclusive) and supplements the above-mentioned publication, presenting additional information relative to the parasites previously listed, as well as accounts of other species found attacking the genus Popillia.

[1] The authors acknowledge particularly the assistance of L. B. Parker, who was assigned to the work in India in 1927; K. Sato, assistant in Japan since 1921; Y. Ouchi, S. Fujii, and Y. Hasegawa. D. B. Langford assisted in the field work in Japan during several seasons. During the progress of the investigations in Japan, Chosen, China, and India the authors received great assistance from the various Government officials. S. I. Kiwana, chief of the Imperial Plant Quarantine Service of Japan, offered every facility for the work in that country. The director and staff of the Chosen Agricultural Experiment Station have kindly provided laboratory facilities at Suigen each season since 1924. The work in China was greatly facilitated through aid extended by Y. Hsuwen Tsou, vice director of the Chinese Bureau of Entomology, and his associates at the National Southeastern University at Nanking, and also by A. W. March, biologist at the Hangchow Christian College, and the authorities of that college, through the provision of laboratory facilities. To T. Bainbrigge Fletcher, Imperial entomologist of India, the senior author is much indebted for valuable advice regarding entomological conditions in India relating to the project, for the determination of Indian insect material, and for the use of the entomological library at the Agricultural Research Institute at Pusa.

[2] Italic numbers in parentheses refer to Literature Cited, p. 57.

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In Japan and Chosen the collection work was continued very much along the lines previously described, with some added investigations upon the parasites of *Anomala orientalis* Waterh., *Autoserica castanea* Arrow, and *Serica similis* Lewis, three additional Asiatic pests found to have become established in the eastern part of the United States during recent years.

The work in China (fig. 1) was initiated by J. F. Illingworth in the fall of 1923 and continued through 1924, when it was taken over by H. A. Jaynes and developed until its abandonment at the end of 1926, the unsettled political conditions in that country making its further continuation impracticable. A portion of the work on Tiphia, however, was continued for the following two seasons in conjunction with that in Japan and Chosen.

The field of investigation in China centered at Shanghai, and extended over the coastal district from Peiping (Peking) southward to Amoy and Foochow, although some scouting was done in the Yangste Valley as far inland as Ichang. The main centers of parasite collection and rearing were in the outlying districts about Shanghai and Foochow.

The Indian investigations (fig. 2) were restricted very largely to the Khasi Hills in Assam, headquarters being at Shillong. This location was chosen, at the time the investigations were initiated, upon the advice of T. Bainbrigge Fletcher, Imperial entomologist of India, and proved exceptionally well suited for this project on account of the abundance of several species of Popillia and certain of their parasites.

In addition to the main fields of investigation, observations were made in Taiwan (Formosa), the Philippine Islands, Java, Malaya, Burma, and Ceylon. Of these, the only ones seeming to offer possibilities for future work are Taiwan and the Philippine Islands.

THE PARASITES AND THEIR BIOLOGY

During the course of the investigations in Japan, Chosen, China, and India the following parasites were studied with a view to their utilization in the control of *Popillia japonica* in the United States. Those species preceded by an asterisk are, under normal field conditions, parasitic upon *P. japonica* itself, whereas the remaining species listed attack other members of the genus Popillia.

	Countries
Parasites of the adult beetle:	
Tachinidae:	
**Centeter cinerea* Ald.	Japan.
**Eutrixopsis javana* Towns.	Japan.
**Hamaxia incongrua* Walk.	Japan, Chosen, China, India.
**Pexomyia genalis* Ald.	Japan.
**Trophops clauseni* Ald.	Japan.
Pyrgotidae:	
Adapsilia flaviseta Ald.	India.
Parasites of the larva:	
Dexiidae:	
Dexia ventralis Ald.	Chosen.
**Prosena sibirita* (Fab.)	Japan, Chosen, India.
Scoliidae:	
Tiphia assamensis A. and J.	India.
Tiphia clauseni A. and J.	India.
Tiphia communis A. and J.	China.
Tiphia matura A. and J.	India.
Tiphia notopolita A. and J.	Japan, Chosen, China.
**Tiphia popilliavora* Roh.	Japan, Chosen, China.
Tiphia vernalis Roh.	Japan, Chosen, China.
Tiphia sp.	Taiwan.

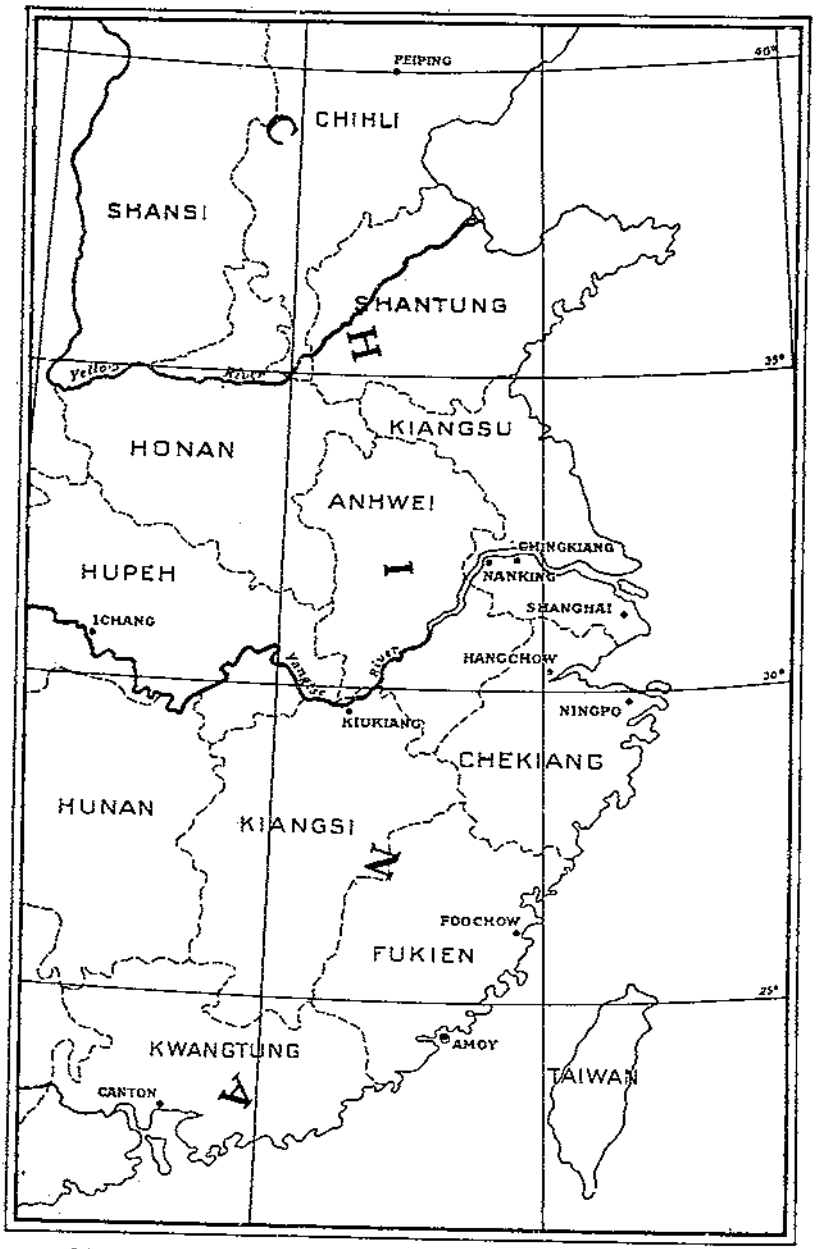

FIGURE 1.—Map of part of China showing the main areas in which investigations on parasites for *Popillia japonica* were carried on.

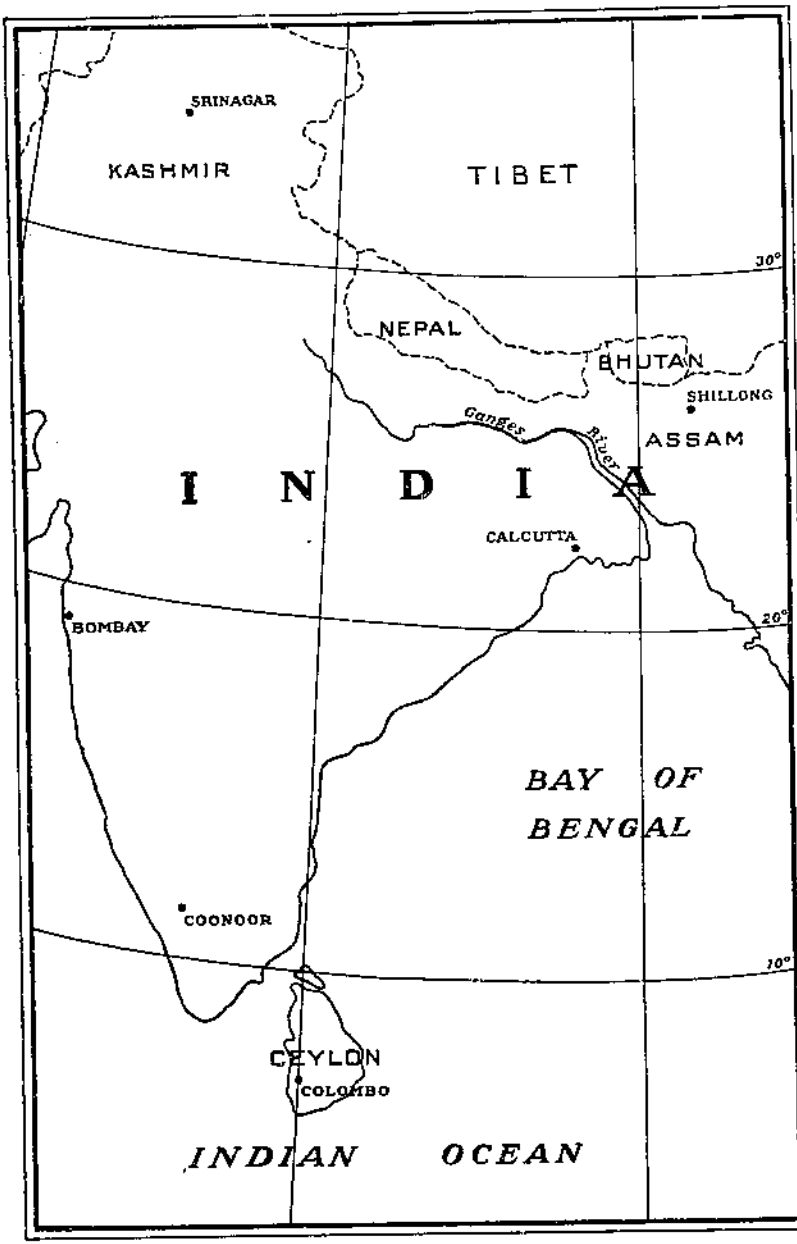

FIGURE 2.—Map of India showing the main areas in which investigations on parasites for *Popillia japonica* were carried on.

In addition, the following species, which normally attack related genera, have been found to be, to a greater or less degree, adaptable to *P. japonica*, and shipments for utilization against that pest have been made:

Parasites of the larva:
Scoliidae:
Campsomeris annulata (Fab.)---------- Japan, Chosen, China.
Tiphia brevilineata A. and J---------- Chosen.
Tiphia biseculata A. and J---------- Japan.
Tiphia koreana Roh---------- Chosen.
Tiphia pullivora A. and J---------- India.
Predators:
Carabidae:
Craspedonotus tibialis Schaum---------- Japan.

This bulletin deals only with the investigations bearing on the discovery of the various natural enemies, their life histories and habits, and the rearing and shipping methods employed in transporting them to the United States. The manner of their handling upon arrival in the United States, their rearing and colonization, and the field distribution and effectiveness of such of the parasite species as have become established, are dealt with in other publications (*2*, *4*, *9*, *10*, *11*, *12*, *13*) from the Japanese beetle laboratory.

PARASITES OF THE ADULT BEETLE

In Japan alone five species of Tachinidae parasitic on the adult of *Popillia japonica* were found, and the attack on other groups of Scarabaeidae, notably the Rutelinae, is very nearly as extensive. It is of interest to contrast this condition with that found in the other fields investigated. In Chosen *Hamaxia incongrua* is the sole representative of the family attacking Popillia, but several other species occur on other genera, notably Anomala. *H. incongrua* was found in all sections, from Japan through Chosen and China to India. As opposed to the condition in Japan and Chosen, and with the single exception noted, not a single species was found on any scarabaeid in China or India during the several years in which the search was made. In the coastal districts of China the adult beetles are almost entirely free from parasite attack of any sort, and in India the place of the tachinids is taken by the Pyrgotidae. It appears that, in the Asiatic regions at least, the groups of Tachinidae having scarabaeid hosts are essentially of temperate rather than subtropical or tropical habit. In general it has been noted that, where these occur, the dispersion is uniform, and the degree of parasitization remains fairly constant from year to year.

TACHINIDAE

CENTETER CINEREA ALD.

The biology of *Centeter cinerea*, a very effective parasite of the adult beetles of *P. japonica*, was quite fully covered in the previous publication (*6*). The work of the next 5 years consisted largely in the continued collection of parasitized beetles and the shipment of additional quantities of puparia for establishing new centers of dispersion, and in strengthening certain of the colonies already established in the United States.

In general, the high rate of parasitization in the field in northern Japan, with its biennial fluctuation due to the partial 2-year life

cycle of the host, has been maintained in spite of the very large numbers of parasitized beetles collected in that section during the last 8 years. Observations in 1927 indicated a parasitization of 47.9 percent of the beetles present from July 15 to 24—a higher percentage than was recorded in 1921 and 1923, corresponding years in the biennial cycle.

The more recent investigations on the distribution of Centeter in Japan have extended its known southern range much beyond that previously recorded, it now being known to occur in several localities in the Tokyo-Yokohama district. When collections of Hamaxia were being made in 1924 at Utsunomiya, about 50 miles north of Tokyo, 20 percent of the beetles taken along the borders of certain wooded areas during the latter part of June bore eggs of Centeter. A small proportion, less than 1 percent, in the Tokorozawa and Narashino districts near Tokyo bore eggs of Centeter in 1928, but a small lot secured June 26 at Hashimoto, about 20 miles west of Yokohama, showed a parasitization of 21 percent. These beetles were dissected, and the stage of development of the larvae contained in them showed that the first oviposition must have taken place about June 20. This is approximately 1 month earlier than oviposition at Sapporo and is correlated with the corresponding advance in the time of emergence of the host. This correlation is rather noteworthy in view of the apparent failure of the species to adapt itself to a corresponding change in the time of appearance of the host in the United States.

SUPERPARASITISM AND EGG DISTRIBUTION

In view of the high percentage of parasitization effected by this species and the extensive superparasitization which unavoidably results therefrom, the determination of whether or not the female Centeter exercises any choice of hosts, avoiding if possible those which already bear eggs, is of interest and importance. A conclusion in this respect cannot be reached by direct observational methods, either in the field or in the laboratory, but it is capable of solution by the analysis of data from series of field-collected beetles showing varying percentages of parasitization and a consequent variation in the proportion of parasite eggs lost through superparasitization.

Curve A in figure 3 shows the percentage of parasitization attained if duplicate oviposition is entirely avoided. In this case the deposition of 100 Centeter eggs on a colony comprising a like number of beetles would result in a parasitization of 100 percent. This very evidently does not occur. Curve B shows the number of eggs which would need to be deposited on the 100 hosts to attain different percentages of parasitization provided chance alone governed the placement of the eggs.[3] It is seen that, to secure a parasitization of 50 percent, the deposition of 70 eggs is necessary, and for 60 percent, 90 eggs. The increase of the percentage of parasitization beyond this point involves the wastage of an ever-increasing proportion of eggs, and the number deposited must be increased to 220 to effect a 90 percent parasitization.

As compared with curve B, representing the result under the law of chance occurrence alone, there is indicated by dots a series of 11 counts

[3] Fiske (8) gives an extended discussion of chance occurrence as it relates to superparasitism, and the curves of figure 3 are taken from his illustration. The dots are from the records of the authors of the present bulletin.

of the actual number of eggs borne by beetles collected in different localities, and the percentages of parasitization indicated. Each count represents from 200 to 1,000 beetles, and the egg number is the ratio to 100 beetles. It is seen that one of the field records falls on the curve of chance occurrence, and that all others fall below the curve.

Had the females shown any preference for unparasitized beetles as against those already bearing eggs or containing larvae, the points plotted would have been between curves A and B rather than below curve B. The fact that they are below this line, however, is not interpreted as indicating any actual preference for beetles already parasitized, but is attributed instead to the fact that those already parasitized, and in which the Centeter larvae have reached the intermediate stage of development, are more sluggish than healthy beetles and consequently offer less resistance to the oviposition efforts of the

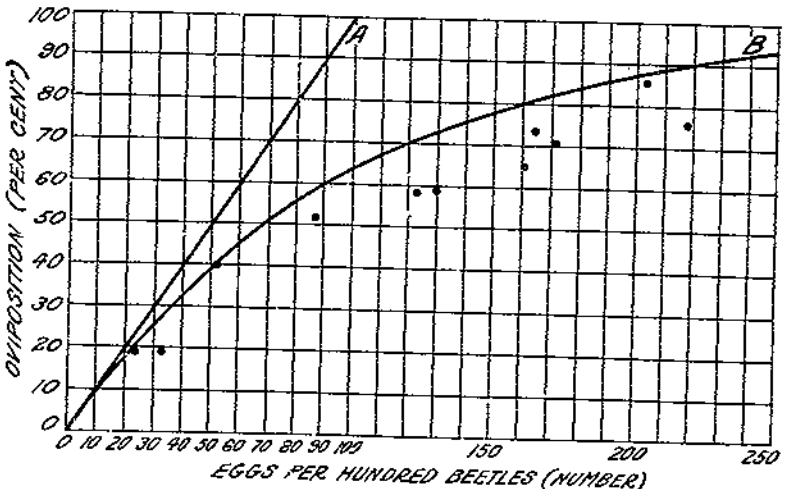

FIGURE 3.—Oviposition by *Centeter cinerea* upon Japanese beetles in the field as compared with the curve of chance occurrence: A, The theoretical result where superparasitism is entirely absent; B, the theoretical result with oviposition governed by chance alone. The dots represent actual field counts of eggs of *C. cinerea* on *Popillia japonica*.

parasite. It is evident, however, that Centeter exercises no discrimination in the choice of hosts, and that the deposition of the eggs is very probably governed by chance alone.

SHIPMENTS

Large numbers of parasitized *P. japonica* beetles have been collected, and the puparia secured from them shipped to the United States each year since 1920, with the exception of 1925 and 1926. The total number of beetles thus collected to the end of 1928 was 603,495, and the puparia obtained therefrom, representing approximately 85 to 90 percent of this number, were forwarded.

There has been little modification in the methods of rearing and packing from those previously employed, or in the care of the shipments en route. Greater care, however, has been taken to eliminate the bodies of dead unparasitized beetles before shipment, thus reducing the amount of decomposition gases generated in the cases during transit.

HAMAXIA INCONGRUA WALK. (OCHROMEIGENIA ORMIOIDES TOWNS.)[4]

In spite of continued experimentation it has not yet been possible to establish by actual observation the exact manner in which *Hamaxia incongrua* attacks its host and in which entrance is effected into the body by the primary larva. Further records have been obtained, however, on development, host relationships, and the extent of field parasitization in the various countries included in this investigation.

The rearing records now available show Hamaxia to have been secured from the following hosts: *Popillia japonica*, *Anomala rufocuprea* Motsch., *A. orientalis*, and *Adoretus tenuimaculatus* Waterh. in central Japan; *Popillia castanoptera* Hope, *P. chinensis* Friv., *P. cyanea* Hope, *P. mutans* Newm., and *P. pustulata* Fairm. in China; and *P. cupricollis* Hope and *P. cyanea* in India. The species is widely distributed throughout the Asiatic and Malayan regions, and it is frequently seen in various tropical countries.

FIELD PARASITIZATION

Field parasitization in the different localities has been exceedingly variable, the general average being low, yet certain small collections of Popillia have yielded approximately 50 percent of parasitized beetles. The attack is always most extensive during the 3 weeks following the emergence of the beetles, and then declines very rapidly.

Owing to heavy collections of Popillia during the previous years, the beetle infestation in the Yokohama district, which in 1921–1923 had shown an exceptionally heavy percentage of parasite attack, has been largely eliminated. In 1924 some collections were made at Utsunomiya, about 75 miles north of Tokyo, and in the following year the greater proportion of the beetles shipped were secured near Kyoto. In the succeeding years the most extensive collections were made in new localities discovered in various suburban districts about Tokyo, and a smaller number in the outlying districts of Yokohama and in the district bordering Sagami Bay, between Kamakura and Akiya.

The highest actual emergence secured at the Riverton, N.J., laboratory from any of the seasons' shipments was that occurring in 1926, when 3.62 percent of the beetles in four consignments, comprising a total of approximately 25,297, collected in the Tokyo-Yokohama section, yielded living flies. Rearings of relatively small lots at the Yokohama laboratory from beetles collected in localities especially favorable for the parasite gave a much higher percentage. The heaviest parasitization was found in the districts immediately south of Yokohama, where collections at Akiya in 1927 showed 17.14 percent of the beetles attacked, while at Sugita in the same year two lots collected on June 23 and 27 showed a parasitization of 14.2 and 24.6 percent, respectively. A small quantity secured at Hashimoto, about 20 miles west of Yokohama, yielded parasite puparia from 41.2 percent of the beetles, and 1,470 beetles collected at Narashino July 11, 1928, showed a parasitization of 33.1 percent. In the districts about Yokohama the general parasitization of Adoretus during this period was found to be 13.3 percent. The heavier attacks by Hamaxia were almost invariably found to occur in rather hilly places with a fairly dense undergrowth, and where beetle feeding was restricted or centered largely upon a rather limited number of favored food plants.

[4] In the previous publications on the parasites of *Popillia japonica* this species was listed under the name *Ochromeigenia ormioides* Townsend, but this has recently been placed as a synonym of *Hamaxia incongrua* Walk., by Townsend, who examined Walker's types in London.

Investigations on the western side of Honshu, where beetles are common but the climate is much colder, showed Hamaxia to be present in very small numbers. No indication of the parasite was found at Toyama and Niitsu, while 0.9 percent of the beetles collected at Nagaoka and only 1 in 250 examined at Tsuruga were parasitized.

In Chosen, China, and India Hamaxia is a very uncommon parasite on the species of Popillia occurring there, and not a single record has been secured showing parasitization as high as 1 percent—in fact only occasional individuals were reared from the several million beetles collected. Though the species is of very wide distribution, its effectiveness seems to be limited to the warmer temperate regions, and there it is of value under special conditions markedly different from those under which the beetle assumes the status of a serious economic pest in the United States.

NOTES ON THE LIFE HISTORY OF HAMAXIA INCONGRUA

The death of the host beetle is brought about by the early third-stage larva 6 or 7 days after its entrance into the body, and pupation occurs about 3 days later. The pupal stage of the first generation lasts 11 to 13 days at the higher temperatures prevailing during late June and July. Emergence of the adult from the puparium takes place almost exclusively between 6 p.m. and midnight—a habit doubtless related to the crepuscular or nocturnal activities of the adult, and in contrast to the morning emergence of most, if not all, parasites of diurnal habit.

A variable majority of Hamaxia develop in female beetles, though not nearly so pronounced a majority as in Centeter. As the larviposition habit of Hamaxia is unknown no explanation can be given for this condition. It has been noted that a considerable number of beetles remain on the foliage of the food plants until late in the evening, and the proportion of these of each sex may determine the relative extent to which they are attacked. In Adoretus the number of each sex attacked was found to be approximately equal.

Laboratory experiments were repeatedly made in the attempt to secure mating and larviposition, but so far as could be determined, mating did not occur in a single instance under the conditions provided. Females were found to contain from 300 to 350 apparently mature eggs in the ovaries within 10 days after emergence, after having been confined with males for the greater portion of that time, yet none of the eggs had descended into the ovisac and consequently no embryonic development had taken place.

The exact number of generations of Hamaxia is uncertain, though there are certainly two and possibly a third, if hosts are available. The first is on Popillia and Adoretus and is numerically much the largest; the following one is on Adoretus and Anomala, owing to the virtual disappearance of Popillia by the time the second brood of females is ready for larviposition. In the investigations in Chosen, particularly where extended adult collections could be made by sweeping, it was found that a considerable number of females were in the field during the latter half of September and in early October, when it was rather cool and no host beetles of any species were available for attack. There is, consequently, a possibility that a portion of the Hamaxia population may pass the winter in the adult stage.

THE SECOND-STAGE LARVA

In the previous publication (*6*) the various stages, with the exception of the second larval instar, were described and figured. This instar is shown in figure 4, with details of distinguishing characters.

Description: Length approximately 2.5 mm, color white. Body broadest in the caudal region, with the last segment broadly bilobed and swollen ventrally. Derm finely striate at margins of segments, as shown in figure 4, B. Posterior spiracles widely separated, each having a dorsally directed hook the surface of which is wrinkled transversely (fig. 4, E). Mouth parts as in figure 4, C and D.

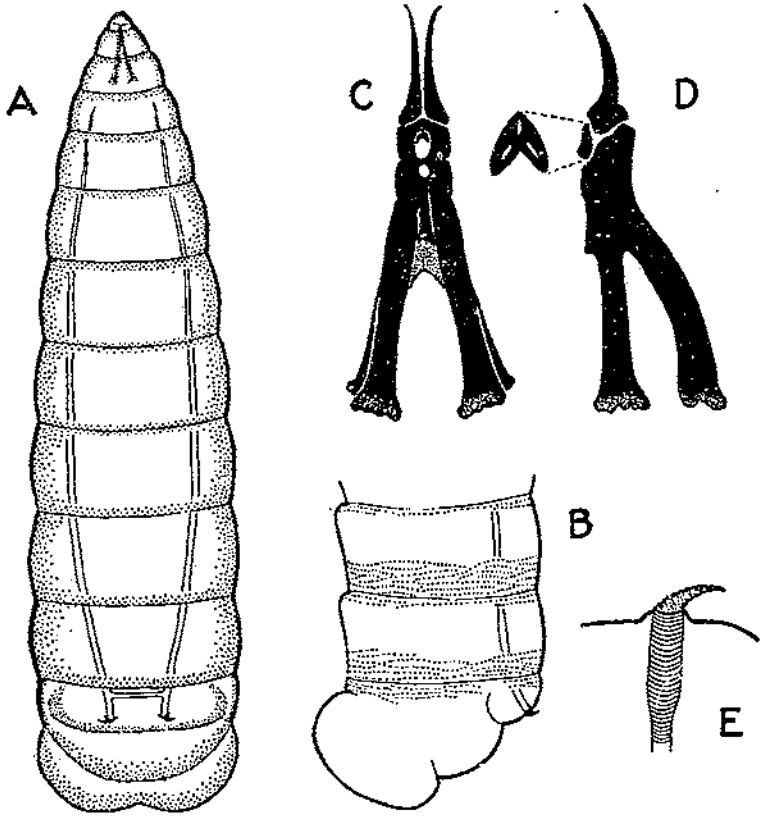

FIGURE 4.—Second larval instar of *Hamaxia incongrua*: A, dorsal view, ×45; B, lateral view of caudal segments, ×45; C and D, the mouth hooks; E, lateral view of caudal spiracle.

SHIPMENTS

During the period from 1923 to 1928, inclusive, a total of 298,000 adult beetles of *Popillia japonica* were collected and shipped alive to the United States for the rearing of Hamaxia. Methods of handling were similar to those previously used, except that refrigeration for any portion of the journey was abandoned, as the condition upon arrival was found to be much better in the case of material kept under normal temperatures.

EUTRIXOPSIS JAVANA TOWNS.

The records of *Eutrixopsis javana* as a parasite of the adult of *Popillia japonica* are based upon the emergence of 210 flies of this parasite in 1923 from the shipments of Centeter forwarded from

Sapporo, Japan, in 1922, and of 78 in 1928 from the shipments in 1927 from the same locality.

In 1928 a particular effort was made to secure further information relative to this species. Through examination of the beetles bearing tachinid eggs, brought in by the collectors, it was anticipated that the egg of this species, if the egg is laid rather than a living larva, would differ sufficiently either in appearance or position on the host to be distinguishable from that of Centeter. However, no information was secured by this means. The later examination of the dead parasitized beetles, and of the puparia contained within them, revealed only Centeter and a small proportion of a sarcophagid scavenger.

Large quantities of beetles free from external tachinid eggs were also set aside and later examined for puparia, but with negative results. More than 100,000 beetles were thus examined, and not a

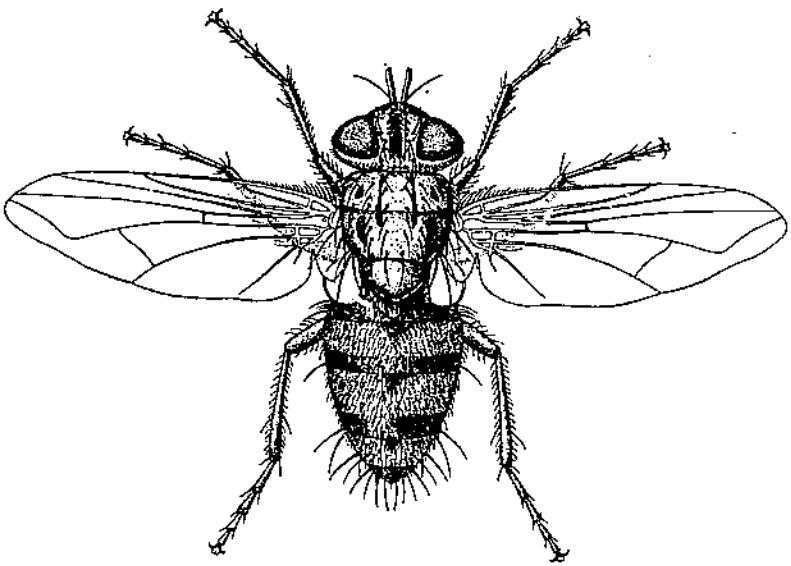

FIGURE 5.—*Trophops clauseni*, adult female, × 7. (Drawing by Y. Hasegawa.)

single Eutrixopsis puparium was found. It is evident that the species is of no consequence as a factor in the control of the host in its native habitat.

PEXOMYIA GENALIS ALD.

The parasite *Pexomyia genalis* was described by J. M. Aldrich on the basis of a small number of adults reared at the Riverton laboratory from adult Popillia collected in central Japan in 1925 and shipped for rearings of Hamaxia. Since that time it has not been encountered in the work in Japan, and nothing is known as to its habits other than that at least two generations a year develop, as indicated by the emergence of the adults in late July from beetle collections made during the latter part of June.

TROPHOPS CLAUSENI ALD.

In an examination of 3,000 beetles collected at Tokorozawa, near Tokyo, Japan, in late June 1928, 1.2 percent were found to be parasitized by tachinid larvae readily distinguishable from those of

Hamaxia and Centeter, which were also included in this host material. Beetles collected a week later did not contain a single individual. Adults have since been secured and described under the name *Trophops clauseni* by Dr. Aldrich.

An examination of the beetles containing these larvae showed them in every case to be free from external tachinid eggs; consequently it

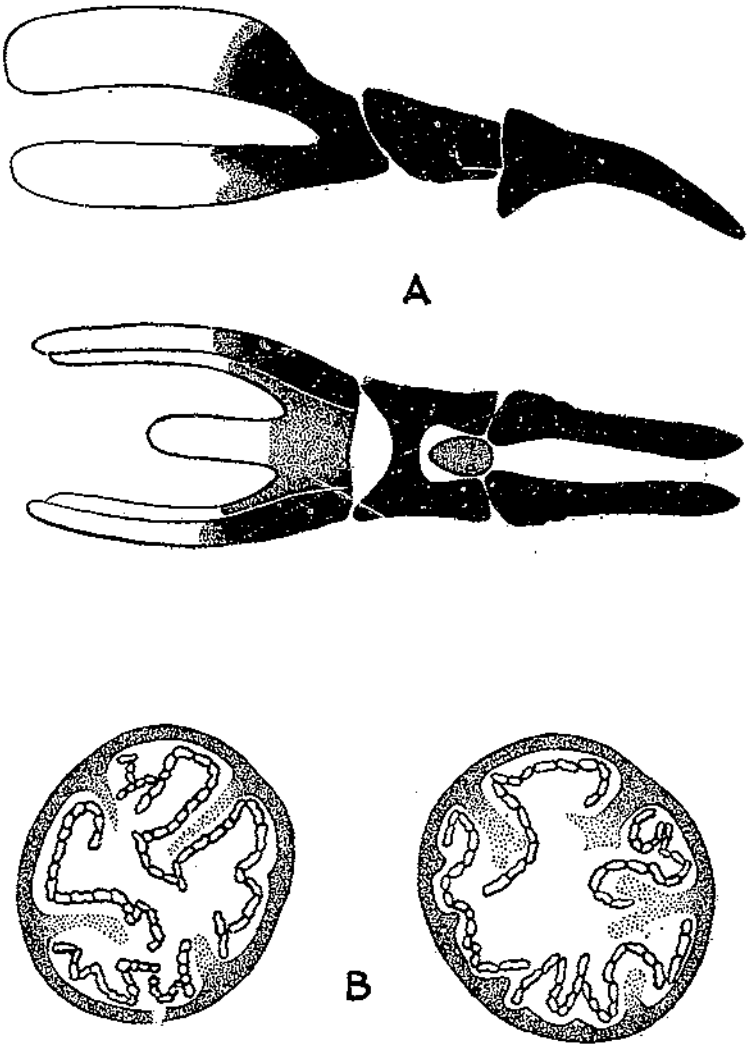

FIGURE 6.—Final larval stage of *Trophops clauseni*: A, Mouth hooks; B, caudal spiracles.

may be assumed that Trophops deposits living larvae much after the manner of Hamaxia. The period of larval development in the host body is longer than that of Centeter and Hamaxia, the maximum period from the collection of the beetles to the pupation of the parasite being 12 days, presumably covering the whole period, as compared with the 9 or 10 days of Hamaxia. The pupal stage lasts approximately 20 days.

The adult female of Trophops is shown in figure 5, and figure 6 shows the mouth hooks (A) and the posterior spiracles (B) of the mature larva, for comparison with those of other tachinids found in the adult beetles. The larval characters serve readily to distinguish the species from Centeter and Hamaxia, the spiracles being sessile, much larger than in Centeter, and closely set together.

PYRGOTIDAE

ADAPSILIA FLAVISETA ALD.

FIELD OBSERVATIONS

The first indications of parasitization of Popillia by *Adapsilia flaviseta* were found in a small quantity of beetles collected August 16, 1925, in a forested area a few miles from Shillong, India. The dis-

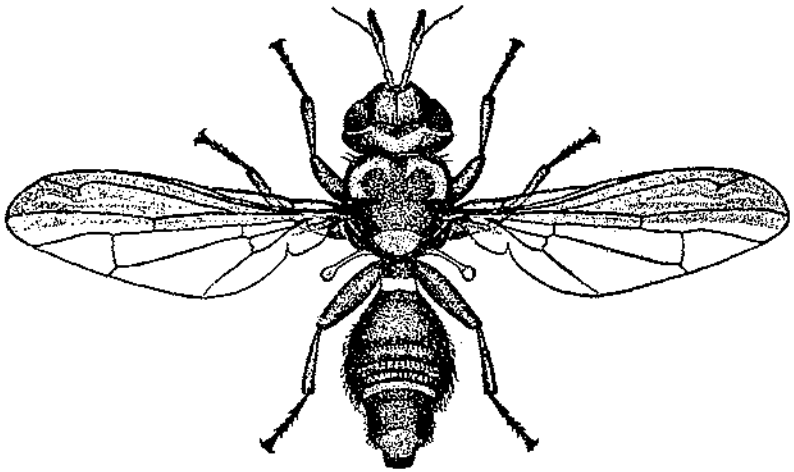

FIGURE 7.—*Adapsilia flaviseta*, adult female, × 6.

section of these beetles revealed that a few of them contained parasitic dipterous larvae quite distinct in form from any of the Tachinidae previously studied in Japan. No adults could be found in the field, but the distinctive central depression or cavity in the last abdominal segment indicated it to be of the family Pyrgotidae. A search in the locality of collection failed, however, to reveal adults of the family at this time. A total of 81,000 beetles (*Popillia cupricollis*) were collected during the period from August 17 to September 20, but from this number only 78 puparia were obtained. Most of these were found in beetles of the first few days' collections, and it was consequently surmised that they represented the last of the parasite brood, the peak of attack having taken place several weeks earlier, and that the percentage secured consequently gave no indication of the total mortality effected.

The few puparia secured were set aside for hibernation and for emergence the following season. The first adult (fig. 7) from this material appeared on July 18, and immediate observations were made in the field in the same general locality which furnished the earlier parasitized material to determine whether the laboratory-emergence

records corresponded to field conditions. On July 20 a single female was captured on a corn tassel in an adjoining field, and from this date onward both sexes were secured in fair numbers. These were determined as *Adapsilia flaviseta* Ald. (*1*).

On the basis of dissections of beetles during this period, it became evident that July 20 was the approximate date of the first oviposition. The great bulk of egg laying occurred during the two weeks following that date, a few females continuing to deposit eggs until August 18 at the latest.

The collection and breeding records, taken in conjunction with field observations, indicate that the correlation between the time of emergence of Adapsilia and that of its hosts is not always so close as might be desired. In 1926 and 1927 this defect was not so evident, as the highe. percentages of parasitized beetles were found among the first-emerging Popillia, whereas in 1928 the greater part of the beetles emerged about 10 days prior to extensive oviposition by the parasite. In this year the period of several weeks preceding parasite activity was marked by heavy rains, which may have induced an earlier emergence of the beetles and also served to delay oviposition by the parasite.

NATURAL HABITAT

The very restricted area in which Adapsilia was found to be most abundant in India is at an elevation of 5,000 to 5,100 feet in a very hilly district largely covered with a widely spaced planting of pine trees, and with a fairly dense undergrowth. Small patches in the ravines and on the hillsides were cleared and planted to corn or potatoes. The host beetle breeds in these forested areas where the undergrowth is rather light, and also at the margins of the more dense areas. The adult beetles feed at various blossoms in this undergrowth and also at corn tassels in the near-by cultivated plots.

The Adapsilia adults were to be found in greatest numbers on the undergrowth foliage in ravines largely screened from direct sunlight, though they occasionally venture into the open fields for food.

PERCENTAGE OF PARASITIZATION

While in certain favored locations, such as those just described, the percentage of parasitization may be fairly high, at times approaching 50 percent, the general attack over the whole area infested by *Popillia cupricollis* has been exceedingly light. The collections for 1926 to 1928, inclusive, covering all of the beetle-infested areas within a radius of 10 miles of Shillong, and the number of puparia secured and the percentages of parasitization each year, are shown in table 1.

TABLE 1.—*Percentage of parasitization of Popillia cupricollis by Adapsilia flaviseta in the neigborhood of Shillong, India, 1926–28*

Year	Host beetles collected	Puparia recovered	Degree of parasitization
	Number	*Number*	*Percent*
1926	451,237	6,420	1.42
1927	508,773	8,141	1.60
1928	771,313	4,097	.53

The decline in the percentage of parasitization in 1928, as compared with that of the preceding 2 years, may be accounted for largely by the constant and thorough collection of all beetles available in the favored localities of the parasite during the preceding years.

SEX OF HOST ATTACKED

A markedly greater proportion of Popillia males than of females is attacked by Adapsilia. This may be due largely to the habits of *P. cupricollis* itself rather than to any actual preference for males by the parasite. Allowing for the sex ratio of the host, approximately twice as many males as females are attacked. Under field conditions the male beetles are active on the food plants during the greater portion of the day, and are on the wing more frequently than the females. The latter feed during the morning hours and then spend a considerable proportion of the afternoon in the soil depositing their eggs. As the parasite attacks the host only while in flight the opportunities for oviposition on the male beetles are considerably greater than those for oviposition on the females.

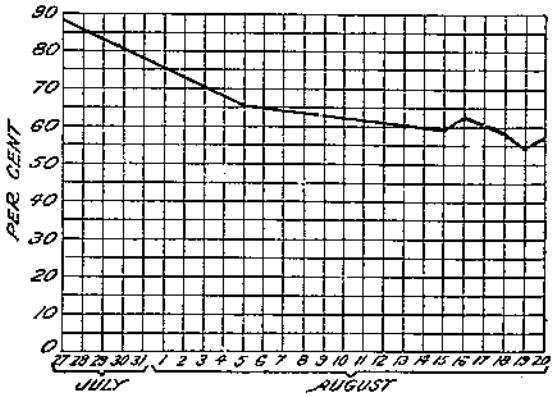

FIGURE 8.—Percentage of males among the hosts of *Adapsilia flaviseta* during the period of attack in 1926.

The percentage of puparia of Adapsilia recovered from male beetles during the season of 1926, as compared with the total of all those parasitized, is shown in figure 8. This is based on an examination for parasitization and host sex of 2,440 parasitized beetles collected on different dates from July 27 to August 20, thus covering practically the entire period of oviposition of Adapsilia in the field. It is seen that in the early portion of the oviposition period, when maximum effectiveness can be attained through the death of the hosts before their extended oviposition has taken place, by far the greater proportion of all progeny are developed in male beetles, whereas the preponderance in this direction is only slight during the latter part of the period. This difference is due to a decline in the proportion of male beetles present and not to a change in habit.

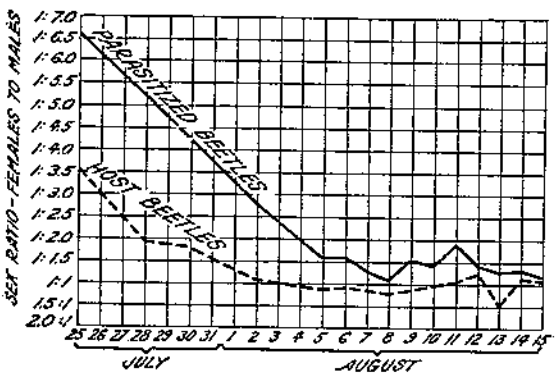

FIGURE 9.—Normal sex ratio of *Popillia* spp. in the field during the time of occurrence of *Adapsilia flaviseta*, as compared with the ratio of those attacked by the parasite, 1927.

In figure 9 the sex ratios are shown for parasitized beetles for the period during which the parasite was active in the field in 1927, as compared with the normal ratio of the host. The records are based on the examination of the dead beetles in the breeding cages, the collection dates of which were known, and the parasitization figures are based on the puparia found in the bodies of these beetles. The figures for the earlier portion of the period are for a total of approximately 500 beetles for each date of record, these being taken at 2- or 3-day intervals, but during the latter portion of the period the count was made daily. At this time unexpected differences were revealed from day to day not evident in the records in the early part of the period, and it is probable that these fluctuations were due to the collection of the various lots of beetles under different conditions and in various localities, and that more representative collections, all taken from the same general locality, would have shown a gradual and consistent decline in both of the curves. Throughout the entire period it is seen that the proportion of male beetles among those parasitized is quite uniformly maintained at approximately twice the normal sex ratio, with a tendency to equalize towards the end of the period. These data correspond closely to those shown in figure 8 for 1926.

OVIPOSITION

The habit of adults of Adapsilia is diurnal, as contrasted with the nocturnal activity of the related Pyrgota as a parasite of Phyllophaga in the United States (7), and this is essential in view of the diurnal habits of the host beetles. Oviposition was observed in the field in many instances, and apparently takes place only while the host is in flight. The female fly remains quiescent upon foliage in the vicinity of the feeding beetle until the beetle takes flight, whereupon the fly immediately pounces upon the beetle from above. The egg is laid very quickly, and the beetle falls to the ground.

Under such laboratory conditions as were available it was not possible to secure oviposition by caged females. The smaller Riley cages used in general insectary work do not provide sufficient room for flight by the beetles and flies, and the necessary outdoor screen cage of relatively large dimensions was not available. Records of development from field-observed ovipositions presented the possibility of error, as the progeny might have come from previously laid eggs rather than from the ovipositions actually observed. This difficulty was overcome by taking to the field beetles which were known to be free from parasites, and inducing oviposition in them. This was accomplished by catching the Adapsilia female in an ordinary insect net and immediately dropping one or more beetles into it. The beetles usually spread their wings before reaching the bottom, and were then attacked by the parasite. In this way one or two ovipositions could be secured from each female, but this was possible only at the moment of collection, as they refused to oviposit when confined and taken to the laboratory.

The ovipositor of Adapsilia is long, relatively slender, flexible, and armed with a heavily chitinized, sharp tip by means of which the integument of the host is pierced. From a dissection of freshly parasitized hosts it appears that the point of insertion of the ovipositor is in the mid-dorsal region of the abdomen near its juncture with the thorax.

LIFE CYCLE

There is a single generation of *Adapsilia flaviseta* annually, the principal host being *Popillia cupricollis*, although a few individuals develop in *P. cyanea* and *P. macclellandi* Hope. The winter is passed in the puparium in the body of the host beetle, which is in the soil or under rubbish on the soil surface. Adult emergence begins in the middle of July, and oviposition takes place the latter part of that month and in the first half of August. The egg stage covers approximately 3 days, and the period from oviposition to pupation is from 15 to 18 days. The host beetles of both sexes are killed by the larvae early in their third stage, 3 or 4 days prior to pupation. The parasitized males live slightly longer than do the females, a condition similar to that noted in Japan in the case of Centeter. The body contents are completely consumed, and the puparium is formed with its anterior end closely appressed to the posterior end of the abdomen of the host. In a very few instances two puparia were found to have developed in a single beetle, though these were below normal in size.

SECONDARY PARASITES

In the breeding work in 1926 the puparia in the trays were found to have become infested with chalcidoid parasites of two species, *Spalangia* sp. and a tetrastichid. The larval forms and method of attack were identical with those previously observed on Centeter puparia in Japan, and it appears that these hyperparasites are of general occurrence upon exposed dipterous puparia in the soil or on its surface, rather than being specific or generic in their host relationships.

COLLECTION METHODS

The manner of field collection of Adapsilia material in India was much the same as that of collecting Centeter in northern Japan. The natives living in the areas infested with *Popillia cupricollis* were shown samples of the beetles and offered 5 annas (11 cents) per hundred for all that they could bring in. This very quickly aroused the interest of a large number of people, principally women and children, and in the later years as many as 80,000 beetles a day were brought in, and collections had to be discontinued before the end of the oviposition period of the parasite because of lack of funds. The area covered by the collectors was approximately 10 miles square. In certain small, isolated infestations the collectors were able to secure relatively large numbers in a short time, but the average payment per person was less than 1 rupee (37 cents) per day. The total cost of collection of the 500,000 to 700,000 beetles secured each year was from $570 to $800.

REARING METHODS

Owing to the fact that *P. cupricollis*, the principal host, is a blossom feeder and that the period of larval development of Adapsilia within the living host is relatively long, it was necessary to adopt a different manner of handling from that used with Centeter in Japan. Manifestly it was impracticable to secure enough blossoms to feed a stock of several hundred thousand beetles for several weeks, and consequently tests were made of various foliage plants, as well as of fruits

and tubers, in an effort to discover some suitable substitute. It was finally found that apples, of which an adequate supply of culls was available at that time, were well suited to this purpose.

Heavy cardboard boxes of approximately one cubic foot capacity were used as containers during the feeding period. A layer of fresh moss was placed in the bottom of each, and upon this enough sliced apples were laid for 500 or 1,000 beetles. The apple pulp decayed very quickly, and the moss served to absorb the excess moisture. The food supply was renewed on alternate days, at which time such of the previous supply as had not been consumed was removed. This feeding was continued for a period of 12 days from the date of collection, and the live beetles then remaining, which were evidently unparasitized, were destroyed. The mortality of unparasitized beetles through unfavorable food and cage conditions was relatively high, though the parasites matured satisfactorily even in beetles which had died during the second larval stage of the parasite, instead of in the third stage as is normally the case.

After the removal of the living beetles, the dead bodies remaining in the boxes were sorted out from the moss with which they were mixed and placed in open trays for drying, as considerable ammonia was being generated through decay, and the Adapsilia still in the larval stage were permitted to pupate. When sufficient time had been allowed for this, the dead bodies were opened and examined for parasite puparia, and to detect and eliminate the large proportion of unparasitized beetles, the unconsumed body contents of which would give rise to decomposition gases in sufficient quantity to affect seriously the vitality of the parasite puparia. In so far as possible the puparia found were permitted to remain in the bodies and were shipped in that condition.

SHIPMENTS

From 1926 to 1928, inclusive, 17,662 puparia of *A. flaviseta* were shipped to the United States. The first year's consignment, of 6,420 puparia, was unfortunately held up in the mails and returned to Shillong several weeks later. It was then repacked and again forwarded by mail, eventually arriving at the Riverton laboratory slightly more than three months from the date of original sending. As a result of this, and also because the puparia were packed too closely and with insufficient means of ventilation, the consignment was a total loss.

The 1927 shipment of 7,601 puparia was packed in small ventilated rectangular tin containers 1 inch deep, with a layer of puparia between two layers of fresh sphagnum moss. A number of such tins were then packed in insect-proof wooden boxes of sufficient size to allow a 3-inch layer of fresh moss to be packed entirely around the series of tins. This consignment was 47 days en route from Shillong to the United States, having been kept at a reported temperature of 40° to 42° F. on the steamer between Calcutta and Boston. Examination upon arrival revealed the puparia to be in good physical condition, with the moss packing still appreciably moist.

The third season's shipment, comprising 3,641 puparia, was packed and forwarded in a similar way, being 50 days in transit at a temperature of 40° to 50° F. en route. Upon examination, 74 percent were estimated to be alive.

PROBABLE VALUE OF ADAPSILIA IN THE UNITED STATES

A consideration of all factors bearing upon this parasite as noted in its natural habitat in India points to a very low potential value as a parasite of *Popillia japonica* in the United States. Its favored habitat, as previously discussed, is markedly different from that in which this host is found in its most destructive numbers in the United States. Then, too, the greater part of the eggs are laid in male beetles, particularly during the early period of attack, a habit in striking contrast with that of Centeter. From the point of view of reduction in host numbers, the ultimate aim in all parasite introduction work, the value of this attack on the males is nil. Further, the longer period of larval development, as compared with that of the other parasites of adult beetles studied, reduces its value still

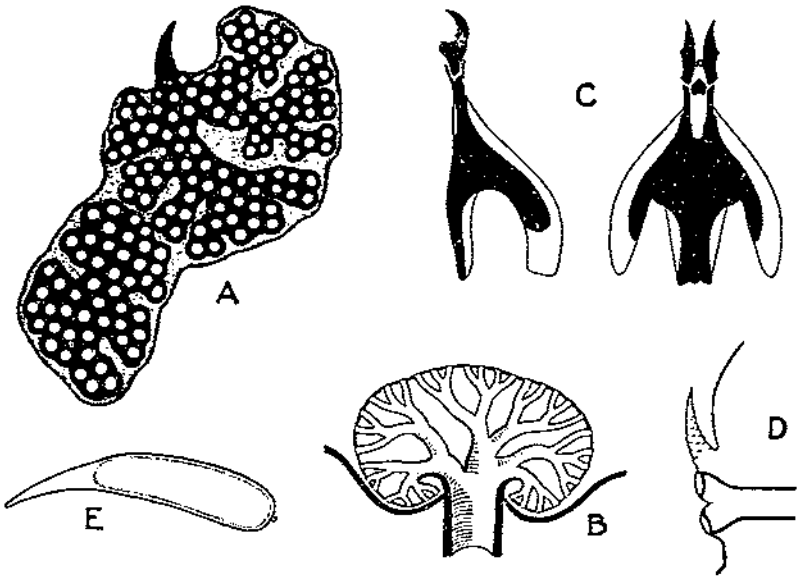

FIGURE 10.—*Adapsilia flaviseta*: A, posterior spiracle of mature larva; B, saggital section of anterior spiracles of third-instar larva; C, mouth hooks of third-instar larva; D, posterior spiracle of second-instar larva; E, the egg, ×30.

more, by permitting oviposition by the host females for a relatively longer period before death ensues. The three principal factors bearing upon parasite effectiveness are therefore, in this case, of minimum value.

CHARACTERS FOR DISTINGUISHING THE IMMATURE STAGES OF ADAPSILIA FLAVISETA

The egg (fig. 10, E): Mature ovarian egg 1.4 mm long and 0.25 mm in maximum width; laid egg 1.3 mm in length. Ventral side pronouncedly concave, dorsal side strongly arched, the anterior half of greatest and uniform width, tapering to a narrow point at the opposite end. Anterior end smoothly rounded, the micropyle large and distinctly button-shaped.

First-instar larva: Body 0.8 mm long, 13-segmented, of greatest width in the mid-abdominal region, with the caudal segments much narrower. Segmentation distinct. Mouth parts much reduced in size and not distinguishable under the higher power of the binocular. Posterior spiracles simple and sessile. Derm with many surface setae or papillae.

Second-instar larva: More robust in form than the first-instar larva, the caudal segments as wide as the greatest body width. Derm with numerous papillae

at middle of each segment, extending around the body. Mouth hooks similar to those of the third instar, but smaller. Anterior spiracles simple and very small. Posterior spiracles (fig. 10, D) separated by their own width and set in a distinct median posterior depression or cavity. Tracheal trunk branched at the spiracle, forming two openings, one above the other, and surmounted by a dorsally directed hook, the surface of which is transversely wrinkled.

Third-instar larva: Body very robust, in fact weevil-like in form, with the derm markedly glistening. Brownish contents of digestive tract distinctly visible. Mouth hooks (fig. 10, C) as illustrated. Anterior spiracles (fig. 10, B, saggital section) slightly stalked and fan shaped, with the tracheal trunk extensively branched. Posterior spiracles (fig. 10, A) very large, of three main lobes, with a dorsally directed hook at the inner dorsal margin, and placed at the dorsal rim of the large median posterior cavity distinctive of the larvae of this family. Ventral lobe extending into the cavity, and the entire surface of the spiracle

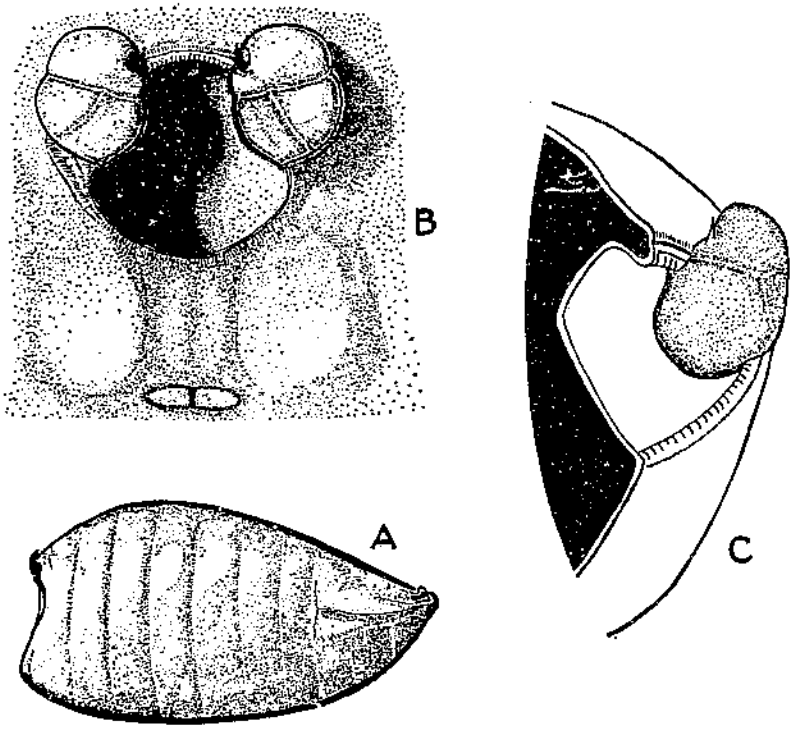

FIGURE 11.—Puparium of *Adapsilia flarincta*: A, Lateral view, X6; B, posterior view showing spiracles and central depression, X25; C, saggital section of posterior portion, X30. (Parker.)

curved through an arc of approximately 180°. Heavily pigmented, the openings being clear and distinct only in freshly molted individuals.

Puparium (fig. 11, A): Length 8 to 10 mm. Distinctly keel shaped and much the widest in the mid-abdominal region. Dark brown or reddish-brown, with reflections dull. Anterior spiracles large and stalked. Posterior spiracles three lobed and placed at the dorsal margin of the posterior cavity, as shown in figure 11, B and C.

PARASITES OF THE LARVA

DEXIIDAE

DEXIA VENTRALIS ALD.

In view of the complexity of the host relationships of *Dexia ventralis* in Chosen, and the danger incident to shipping it in living grubs other than those of *Popillia japonica* owing to the risk of an escape

of these species, no shipments were made until 1925. In the meantime the establishment of *Anomala orientalis*, *Autoserica castanea*, and *Serica similis*, three scarabaeid beetles of Asiatic origin, in the eastern part of the United States made more possible the success of the importation by providing at least one of the alternate hosts thought to be necessary in the annual cycle of Dexia.

This species is known to occur in Chosen, Manchuria, and the Malayan region, but extended observations have failed to reveal this or any other species of the genus as parasitic in scarabaeid grubs in the coastal sections of China and in India.

LIFE HISTORY

In the further life-history studies which have been made of this species during 1924 and 1928 additional facts have been revealed relative to the host relationships of the species, and these were found to vary considerably from year to year owing to the changing host population in the soil. In figure 12 is shown the developmental cycle for 1924, starting with the overwintering larvae in the various host grubs. In that winter the young larvae were largely contained in grubs of *Miridiba koreana* N. and K., *Popillia castanoptera*, and *Phyllopertha* spp., and on examination in the early spring they were found to be in a healthy and active condition in all of these hosts. As time went on, however, it was found that those in Phyllopertha were dying gradually, and in the end all disappeared without reaching maturity. Those in Miridiba developed normally and pupated during May, the first brood of adults appearing in the field late in May and during the first half of June. The progeny of these flies parasitized the mature grubs of *Popillia castanoptera* then available, and a second brood of adults resulted late in July and during the first half of August. The larvae produced by these females in turn found only Serica grubs in suitable condition for the production of another generation, and the third and final brood of adults developing from them appeared during September and the first half of October. The progeny of these females were then distributed among the various host-grub species, suitable and otherwise, occurring in the soil at that time. It is thus seen that in the three-generation phase of *Dexia ventralis* each generation develops in a different scarabaeid subfamily, namely, Melolonthinae, Rutelinae, and Sericinae, respectively, the overwintering host being listed first.

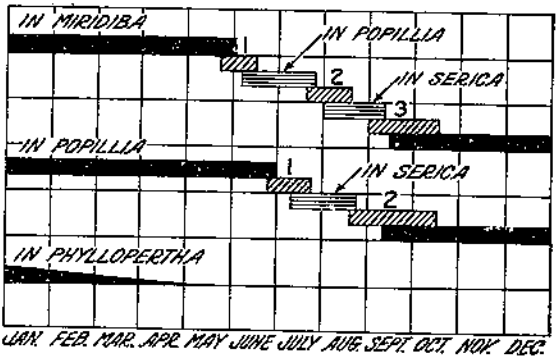

FIGURE 12.—Seasonal cycle of *Dexia ventralis* in different hosts in Chosen in 1924. The numbers refer to the successive broods of adults of the parasite, the heavy black bars are the overwintering grubs, and the horizontal-ruled blocks represent the summer grubs.

The cycle of three generations, however, represents only a portion of the Dexia population. Those individuals overwintering in Popillia are delayed in development and reach maturity and pupate

from the middle to the end of June, approximately 1 month later than those in Miridiba, as the host attains the proper stage at a later date, and consequently the adults appear in the field at the end of June and during the first 3 weeks in July. This is too late for the production of the succeeding generation on the same host, as practically all have either pupated or already emerged. The enforced alternative is therefore to attack directly the Serica grubs then available, and this attack consequently takes place somewhat earlier than that of the second generation from Miridiba. The adults of the second brood from Popillia emerge somewhat earlier than those of the third from Miridiba but persist for a longer period, the activities of both being terminated by the advent of cold weather in the middle of October. Thus, with Popillia as the winter host it is found that only two generations a year are produced instead of three.

The complexity in the host relationships as just described and the life cycle of the parasite result in the presence of adult flies in varying numbers in the field throughout the season. It is possible, however, to distinguish the successive broods of adults by the numerical peaks attained after emergence. The apparent first brood, as distinguished from the complete first generation, is numerically the greatest, while the apparent second, which develops entirely from Popillia, is in part the actual first from those overwintering in that host and in part the second from those overwintering in Miridiba. The apparent third brood of adults is from Serica alone, representing the actual third from the original Miridiba and the second from Popillia.

This evident adaptability of Dexia to the conditions of the host species, as opposed to the previously considered obligatory alternation, enhances greatly the potential value of the species as a parasite of *P. japonica* in the United States. It appears improbable that the alternate hosts can be entirely dispensed with, and the presence of at least one of these would seem to be essential to the attainment of an effective status against *P. japonica*. In general it may be said that the advent of an obligatory alternate host into the economy of a parasite species results disadvantageously unless the former is at least numerically equal to the host to be controlled. The factor of numerical abundance of the host has a particular bearing in this instance as determining directly the percentage of parasite planidia which ultimately find hosts and develop to maturity.

An examination of the habits of the first-stage larva reveals that it exercises no apparent discrimination in the choice of host grubs, and that the factor influencing the relative degree of attack upon the various grub species is the physical character of the grubs themselves. In connection with the hibernation experiment in 1928, records were made of the percentage of penetration effected upon the various host species in different stages. Included in this series were grubs of *Popillia castanoptera*, *P. atrocoerulea* Bates, *Miridiba koreana*, *Phyllophaga* sp., *Phyllopertha* spp., *Anomala* spp., and *Serica* spp. Two methods of securing parasitization were used, those of direct application of planidia to the grubs by brush and the caging of gravid females over soil containing grubs.

Under identical conditions a marked variation was noted in the percentage of grubs containing planidia after a certain period in the cages or the inoculation blocks. In the inoculation cells, with from 5 to 10 planidia placed directly upon each grub, which was then cov-

ered with soil and confined therein for 2 days, the general rate of parasitization was good with both species of Popillia, with *Miridiba koreana*, mature Serica, and second and early third stage Phyllophaga, medium in the smaller species of Anomala and early second-stage Serica, and very poor in the large Anomala and in third-stage Phyllopertha. The extremes in results were represented by an 18 percent parasitization of the larger Anomala as contrasted with an 85 percent parasitization in the second and early third stages of Phyllophaga. It is very evident that if this result is indicative of preference or greater physical suitability, then the instincts of the larva are greatly at fault in choosing above all others a host species in which development to maturity cannot possibly occur. An examination of this series of grubs, however, indicated that the relative thickness and toughness of the integument of the host grubs is the determining factor. The larger Anomala has an exceedingly heavily chitinized integument, its surface covered with numerous setae, as compared with the very thin and bare integument of the second and early third stage larvae of Phyllophaga. The other species listed may be considered as intermediate between these two in this respect. The lower percentage of parasitization of early second-stage Serica, as compared with the mature grubs of the same species, is attributed, not to the above-mentioned factor, but to the very small size and great activity of the young grubs themselves in relation to the space and volume of soil in the inoculation cells. Their activity results in the planidia being quickly brushed off the body, and the relatively far greater volume of soil present then renders the finding of the grub again correspondingly more difficult. Also there is a lack of intersegmental sutures on the body to provide the more ready points of entry.

Two principal mortality factors are involved in the life of the early larval stages in the host, the first being the defensive reactions set up by the host body, largely represented in this instance by Phyllophaga, and second, the molting of the host, resulting in injury and death to the parasite. In unsuitable hosts death is brought about by phagocytic action and occurs largely in the first larval stage, and occasionally in the second. The respiratory funnel attachment to the host derm is broken after death, and the body of the parasite becomes a darkened, encysted mass imbedded in the host tissues near the original point of entry. In the molting of the normal hosts some of the larvae are killed, but their death does not inevitably follow, the general result being merely the loss of the respiratory funnel with the host exuvium, the larva remaining with its posterior end fixed in the aperture in the integument of the succeeding stage, and eventually forming another funnel.

As in *Prosena sibirita*, it has been determined that although the normal condition is for the larva to attain maturity and pupate only in grubs which themselves are undergoing histolytic action preparatory to pupation, yet this is not an essential condition, and the changes and development to maturity can be accomplished in immature host grubs.

REARING AND SHIPPING METHODS

The breeding work in preparation for shipment to the United States was started in 1925. Grubs of *Popillia japonica* only were used, and these were shipped south from Hokkaido to Fukuoka in Kyushu, to which place the Dexia females from Chosen were also forwarded.

This was made necessary by the fact that *P. japonica* does not occur in Chosen; consequently the risk of its accidental introduction into that country could not be taken. The supply of *P. japonica* grubs of the proper stage of development was very limited, that year (1925) being the one in the biennial cycle of the beetle in which all grubs pupated and emerged. By the time a sufficient supply of gravid females of Dexia was available, late in June, a very high percentage of the grubs collected had developed beyond the stage of usefulness for parasitization.

The following year (1926) the fall brood of adult flies was used for the artificial parasitization of 2,500 native grubs, largely *P. castanoptera,* and these were placed in hibernation quarters under sod during the winter. They were dug up at the end of the following April and yielded 115 puparia, 130 mature larvae, and 699 larvae still within the living host grubs.

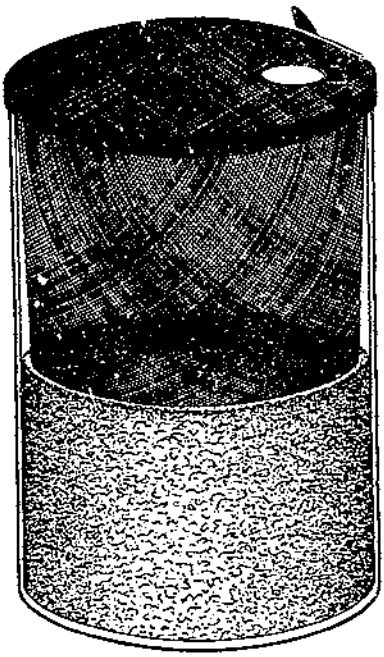

FIGURE 13.—Breeding jar used in the parasitization work with *Dexia ventralis.*

In 1927 it was arranged to utilize the native grubs in Chosen as hosts during shipment, special precautions being taken in packing and in handling on arrival to eliminate any possibility of escape. Breeding work was carried on with females caged over soil containing grubs, and by placing planidia dissected from gravid females on the grubs, the method previously perfected for use with Prosena in northern Japan. From the first brood of flies 1,200 females were dissected and the planidia obtained placed upon 8,824 grubs, 4,463 of which were successfully parasitized.

With the second brood of flies the breeding-jar method was adopted as being less laborious and less wasteful of the parasite supply, which was not so great as in the preceding generation. One-quart glass jars were fitted with copper screen cages (fig. 13), and 20 to 30 grubs were placed in soil in the bottom of the jar and 5 or 6 flies in the cage above. The grubs were examined daily, and those showing parasite penetration, as evidenced by the respiratory funnel attached to the derm, were removed. By this method 6,060 grubs were parasitized by 492 Dexia females. It was found in this and the later work that a general average of 1 to 1.5 successfully parasitized grubs a day could be obtained from each fly.

Experiments were conducted in the shipping of field-collected females from Chosen to Yokohama for use in breeding work there. In a consignment of 200, which was 2 days in transit, only 3 were found dead on arrival. The shipping containers were the same as those used in forwarding scoliid adults to the United States (fig. 16),

the only change being the substitution of soil for moss in the bottom of the tins; thus any planidia deposited en route would be alive and could be used on arrival. The maximum length of life of the flies shipped was 19 days during relatively cool weather.

The life of the planidia in the soil was found to be shorter than had been supposed. Relatively few grubs were parasitized after the fourth day, though a few parasitizations were obtained up to the seventh day.

SHIPMENTS

The first consignment of parasitized grubs was forwarded in 1925, consisting of 850 of *P. japonica*; this was followed by 8,624 of various suitable hosts from Chosen in 1926, and 864 of the same and of already-formed Dexia puparia, with 10,986 grubs of *P. castanoptera* alone in 1927. The duration of the life cycle of the parasite is such that the majority of the flies are in the pupal stage and ready for emergence on arrival at the laboratory in the United States.

PROSENA SIBIRITA (FAB.)

FIELD OBSERVATIONS

The dexiid *Prosena sibirita* is an important parasite of the grubs of *Popillia japonica* in northern Japan. Elsewhere, however, even though adults may be observed in abundance, only an occasional individual of the various species of Popillia can be found containing its larva.

This species is generally distributed throughout the entire Asiatic and Malayan regions, and adults were commonly seen during the course of the investigations in Chosen, China, and India. In northern Japan it is primarily a parasite of *P. japonica*, normally effecting a field parasitization of from 10 to 15 percent, and it also occurs to a lesser extent on Anomala and Serica. In Chosen an occasional larva was found in Popillia and in various sericine grubs, whereas in China no record of the species as a parasite of any of the Popillia occurring there was made during the 4 years of investigation in that country. In India it was noted that a very few field-collected grubs of *P. cupricollis* contained Prosena larvae, but by far the greater number of the parasites were found in the various species of Serica. In Java *Prosena sibirita* is recorded as a parasite of Adoretus.

As a result of the earlier studies upon the habits of *Prosena sibirita* in northern Japan it had been concluded that the final stages of development of the larva could take place only in host grubs which themselves were undergoing histolytic action preparatory to pupation; and this conclusion was borne out by the time of appearance of the adult flies, which in that section appeared in the field about 2 weeks after the time of emergence of the host beetles, and persisted until September. It has since been found, however, that this condition is not essential, even though normal, as some larvae complete feeding and pupate from smaller grubs which would otherwise carry over until the following season before attaining maturity.

At Shillong, India, the earliest observation of adult flies in the field was April 9, when several females were seen feeding at the blossoms of apple, and they were present continuously from that date until the end of September. Those which were reared from *Popillia*

cupricollis emerged at the end of June, and those from Serica in July. The parasitization of the latter host at this time was found to approximate 25 percent.

During the earlier investigations on this species at Koiwai, Japan, it was noted that there were three forms of adults of Prosena in the field, differing appreciably in size, coloration of the abdomen, and somewhat in the time of appearance. It was assumed at that time that these represented distinct species, and their hosts had been determined as *Serica* sp., *Popillia japonica*, and *Anomala* sp., respectively, in the order of size of the adult flies. Aldrich, however, has made repeated examinations of all characters of these forms, including the genitalia, and declares them to be specifically the same. The intermediate and smaller forms only were noted at Sapporo, whereas in Chosen during the late summer only the large form is to be seen. The variation in the size of the three forms and their differing times of emergence could result from corresponding differences in the host species, but the distinguishing coloration of the abdomen of these forms can hardly be explained on the same basis.

BREEDING AND SHIPPING METHODS

During the first two seasons' investigations upon *Prosena sibirita* (1921 and 1922) a method was devised whereby host grubs in large numbers could be artificially parasitized with the first-stage larvae taken from the ovisacs of the gravid females, and these grubs then shipped immediately. In the following 5 years this method was abandoned in favor of the forwarding of field-collected grubs, which showed a general parasitization each year approximating 10 to 15 percent. Collections were made in Hokkaido in the early spring and forwarded in late May, so as to arrive at the laboratory in the United States just before emergence. This method proved satisfactory, as the emergence of adult parasites was estimated at 70 percent of the original parasite content at the time of collection. The cost involved, however, was considerable as, aside from the cost of collection and crating in Japan, each consignment of grubs (25,000 to 50,000 packed in soil) involved a heavy expenditure for transportation.

Because of the cost handicap, as explained above, the artificial parasitization of grubs in the late summer and fall was again taken up in 1927. Instead of being shipped immediately, however, these parasitized grubs were placed in a prepared soil plot, well drained and covered with sod, where they were left for the winter. To prevent the grubs wandering away, the plot was inclosed to a depth of 18 inches in fine-mesh screen, the surface being also covered with the same material to prevent loss by rodents and birds.

When the parasitized grubs were overwintered as above, the proportion available for shipment the following spring was approximately 60 percent. Owing to their high parasite content, the shipping cost was thus reduced to about 20 percent of the previous cost of shipping an equal number of parasites.

The shipping containers used in the earlier consignments provided about 3 cubic inches of soil and grass roots for each grub, the cases being separated into compartments by cross-section sets of wood, zinc, or tin. The shipments of 1927–28 were contained in tin-lined boxes 1 foot square and 6 inches deep, inside, each containing five cross-section sets separated by tin plates and providing a compart-

ment of approximately 1 cubic inch for each of 500 grubs. It was found unnecessary to provide grass roots for feeding in transit, and the soil used was first thoroughly screened and then fumigated with carbon disulphide to eliminate any other soil-inhabiting insects which might be present.

SHIPMENTS

From 1921 to 1928 13,600 artificially parasitized grubs and 159,000 collected in the field, the latter having a general parasite content of about 10 percent, were shipped from northern Japan to the United States. In addition, 40,596 grubs were artificially parasitized in the late summer of 1928 and placed in winter quarters, to be forwarded the following season.

SCOLIIDAE

During the course of the investigations on parasites of Popillia in Japan, Chosen, China, and India during the period from 1920 to 1928, inclusive, a large number of scoliid species, principally Tiphia, were found to attack the grubs of this genus. The habits of these species, as well as those of many on other scarabaeid genera, have been intensively studied.

In general the conclusion has been reached that, under conditions such as exist in agricultural sections in Asia and in the United States, Tiphia is unable to achieve the role of an important controlling factor in the economy of its hosts. In the case of a great many species of Tiphia localized infestations have been observed in which relatively high percentages of host grubs were attacked, but none of the species has been seen to occur in numbers sufficiently great throughout the entire host habitat to exert any appreciable check upon it. There is little basis for hope of greater effectiveness by any one species under the conditions existing in the sections of the United States now inhabited by Popillia, though there may be some possibility that the aggregate effect of a series of species might contribute appreciably to its ultimate control.

One of the main limiting factors bearing on Tiphia is that of the food supply of the adults, which is derived from three general sources—the honeydew secreted by aphids and other bugs, the blossoms of various plants, particularly Umbelliferae and Polygonaceae, and the nectar glands associated with the foliage of certain plants, such as Polygonum and sweetpotato. The spring species in general feed upon insect secretions, the summer species on these and also at various blossoms, and those occurring in the fall at blossoms and nectar glands. It is thus evident that the maintenance of a large Tiphia population throughout the season is entirely dependent on the presence of aphid-infested plants and of the various weeds bearing suitable blossoms and nectar glands. This condition is in opposition to the best agricultural practice, which involves the elimination of weeds and the control of such bugs as infest cultivated crops. These latter may occur in limited numbers, but again they may be entirely absent over large areas heavily infested by the beetle.

In only a single instance, that of *Tiphia matura* in India, has a scoliid been known to have its normal source of food supply at an appreciable distance from the host infestation, and to continue this condition from year to year. The more usual development in the event of failure of the local food supply is mass migration to another

locality for oviposition as well as feeding. Even with the food supply available in the immediate vicinity, the fluctuation in numbers in a given locality from year to year is very great.

Another factor affecting Tiphia adversely in cultivated sections is the destruction of the cocoons through soil cultivation. Were the mortality of host grubs proportionately as great, the numerical reduction would have no serious result, but such is not the case. Very few Scoliidae are able to reach maturity and emerge where the soil cell in which the cocoon has been formed is broken. This factor is of little consequence in relation to Scolia or Campsomeris, as with these genera the host grub is usually buried and the cocoon is formed considerably below the customary depth of cultivation.

The host relationships of the various species of Scoliidae parasitic upon scarabaeid grubs have been found to be generally within generic rather than specific limits. In any given locality, however, each species confines itself very largely, and at times entirely, to a single host species. This apparent specificity may be obligatory, as in the case of *Tiphia popilliavora* in Japan, where it is due to the presence of only the one species of the host genus in the locality, though it may extend to different hosts in other regions.

The life cycles of the species of Tiphia occurring in the Temperate Zone are similar, there being usually a single generation each year, and the winter being passed within the cocoon in the soil. Comparatively few of the species that occur in the warmer localities produce 2 generations annually, though as many as 5 or 6 may develop under optimum conditions in the Tropics. The dormant stage in temperate regions may be either the mature larva, the pupa, or the adult in the cocoon, the latter being the case with those species that emerge early in the spring, and which presumably would produce a second generation annually under slightly more favorable conditions.

In all of the species of Scoliidae studied, comprising the genera Scolia, Campsomeris, and Tiphia, the egg position on the host grub has been found to be a specific constant. In figure 14 this position is illustrated for all of the species discussed in this bulletin.

Campsomeris annulata Fab.

General observations

While there was considerable doubt regarding the ability of *Campsomeris annulata* to adapt itself successfully to *Popillia japonica* as a host in the United States, yet the comparative facility with which it could be secured in numbers permitted an extensive experimental program in 1925 and 1926. The native hosts of this widely distributed scoliid are usually the grubs of the larger ruteline species, particularly species of Anomala and at times *Phyllophaga diomphalia* Bates, and its range in host groups is considerably greater than is found in Tiphia. Under American conditions it was hoped that at least one of its multiple generations would develop upon *P. japonica*. However, the large-scale importations and colonizations have apparently failed of establishment.

The life cycle under experimental conditions varies considerably with changing temperatures. In Chosen in midsummer the durations of the stages were 2½ days for incubation of the egg, 5 days in the larval-feeding stage prior to the formation of the cocoon, and 21

days in the cocoon. These figures may be taken to represent the minimum developmental cycle of the species.

In Japan and Chosen there are apparently three generations a year, the winter being passed largely in the pupal stage in the cocoon. In the coastal sections of China an additional generation is produced. In Chosen the first adults were seen in the field April 30 and persisted throughout the season, the broods being largely intermixed, and the last of these most abundant during October. In China the first individuals were taken on March 8; the first brood was at its peak during the middle of May, the second in the latter part of July, the third at the end of August and in early September, and the last at the end of September and in the first half of October. There are some indications that a portion of the last brood of adults hibernates during the winter in that stage, but this point has not as yet been demonstrated conclusively.

The adults feed exclusively at various blossoms, particularly those of thistle, wild carrot, white clover, *Vitex negundo*, and goldenrod, and never on the liquid excretions of insects. The females are seen

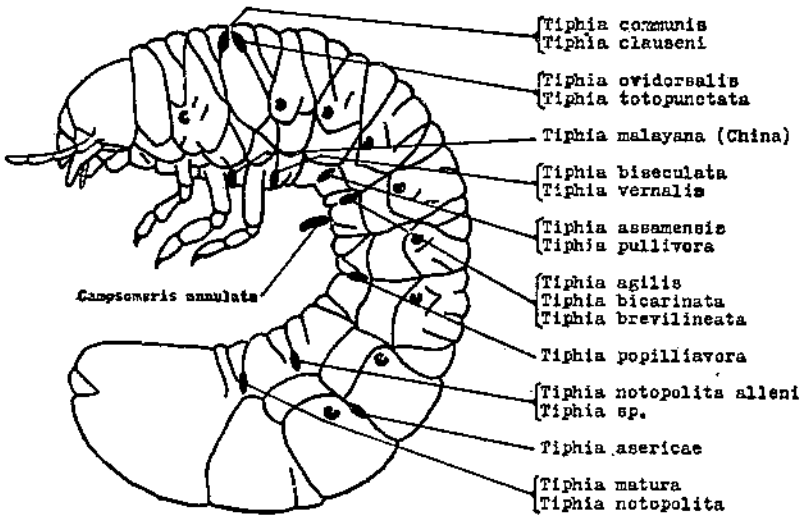

FIGURE 14.—The position of the eggs of various Scoliidae on the host grub.

largely during the morning hours and until 1 p.m., the males predominating during the afternoon.

REARING METHODS

Owing to the permanent paralysis of its various host grubs at the time of oviposition by Campsomeris, the methods of rearing and shipping the immature stages differed considerably from those employed with Tiphia. In Chosen 1,000 ovipositions were obtained in 1925, though with some difficulty, as the females did not oviposit readily in captivity. During the egg stage there was considerable loss through the death of host grubs and from the parasite egg being rubbed off by relatively slight movements of imperfectly paralyzed hosts. The 1,000 ovipositions finally resulted in 219 cocoons being formed. Similar methods employed in China gave much better results.

In the following season's work, both in Chosen and China, individual clay cells were used for shipping purposes, the paralyzed grubs being placed therein as soon as the eggs had hatched. These cells were first soaked in water, the grubs were inserted with a small quantity of moist moss, and the cells were corked. The cells were then packed in wooden containers, with a considerable quantity of moist moss, and immediately forwarded.

The proportion of cocoons formed in the cells en route ranged from 10 to 53 percent, the most successful shipments being two small lots from China in 1926 yielding 46 and 53 percent, respectively. The general average, however, was low, and in view of the success attained in shipping adult females the more laborious rearing method was abandoned.

It is interesting to note that a variable proportion of the paralyzed grubs forwarded upon which the parasite larva did not develop were still alive on arrival in the United States. The maximum percentage of these in any one shipment was 75, and these were examined approximately 30 days after parasitization.

SHIPMENTS

The shipments of *C. annulata* forwarded from 1923 to 1926, inclusive, comprised a total of 348 reared cocoons from Chosen and China, 6,416 parasitized grubs in cells from Chosen and China, of which all but 219 were from the latter country, and 31,060 adult females from Japan, Chosen, and China, by far the greater number of these also coming from China. In all the shipments in 1925 and 1926 the best results were secured from the early second and the third broods of adults. October collections gave the best percentages of survival but were of no value on arrival owing to the lateness of the season. A general average of 13.6 percent of all of the females forwarded, representing all generations, were alive on arrival, these numbering 4,219. The highest percentages of survival were in two consignments forwarded from Shanghai in October 1925, amounting to 78.3 and 82 percent, respectively. The duration of the collecting period prior to shipment was 7 to 15 days, followed by 14 to 17 days en route from Japan and 21 to 27 days from China.

Table 2 is a summary of the records for the various shipments from Japan and China, arranged according to the month of collection and shipment, and giving the totals and percentages of survival.

TABLE 2.—*Summary of shipments of adults of Campsomeris annulata, 1925–26*

Month	Shipped from—	Parasites shipped	Parasites surviving	
		Number	*Number*	*Percent*
May	China	5,155	688	13.3
June	do	7,500	838	11.2
July	do	7,223	249	3.4
Do	Japan	1,302	244	18.7
August	China	7,571	921	12.2
September	do	1,032	257	24.9
October	do	1,277	1,022	80.0
Total		31,060	4,219	13.6

TIPHIA POPILLIAVORA ROH.

GENERAL OBSERVATIONS

In Japan, *Tiphia popilliavora* was found in abundance at Koiwai, Iwateken, in 1920, and breeding work was conducted in that locality for several years. With the exception of those from this locality, and the record of three individuals taken at Yokohama in September and October, 1921, not a single specimen of the species has been collected in the islands of Japan during the eight years the investigations have been in progress. This very localized distribution is surprising in view of the wide distribution, under greatly differing climatic conditions, of the host. The present known range of distribution of the species, outside of Japan, extends to Suigen, Chosen, and Penniu and Hangchow, China, and in these countries also the same markedly localized distribution occurs.

In the previous publication (*6*) a fairly extended account of the life history and habits of *T. popilliavora*, as determined at Koiwai, was given, and the additional data here presented deal with the species on other hosts, and under different climatic conditions, in China and Chosen.

On the basis of the taxonomic studies of Allen and Jaynes (*3, p. 53*) on the Asiatic Tiphia, based largely on the collections made during the course of this parasite project, *T. popilliavora* is represented by three strains, or races, which occur in Japan, Chosen, and China, respectively, and present only very slight morphological differences. The Japanese race is parasitic on *Popillia japonica* alone, the Chosenese on *P. atrocoerulea* and *P. castanoptera*, and the Chinese race on *P. formosana* Arrow, *P. chinensis*, and others of the same genus.

LIFE HISTORY AND REARING RECORDS

In time of emergence in the field the northern-Japanese form ordinarily appears first, occurring from August 15 or 20 to the middle of September, whereas in Chosen the duration of the period is of about the same length, but the first appearance varies from year to year between the middle of August and the middle of September. In China (Penniu) the adults appear the latter part of September and persist until the middle of October. Thus in these localities the period of adult presence in the field is during the few weeks immediately preceding the cooler period of fall, which naturally begins earlier in northern Japan than in the more southern latitudes.

The egg is placed ventrally between the fifth and sixth abdominal segments, and this position is constant for the Japanese and Chinese forms, but at Suigen, Chosen, as a parasite of *Popillia atrocoerulea*, the more general position is between the sixth and seventh segments.

A comparison of the rearing records of the respective races reveals several points of interest. Upon *Popillia japonica* at Koiwai, Japan, the maximum number of eggs obtained from a single female was 47, the general average being less than 15 for the several hundred in the breeding series. In contrast to this, a female collected at Penniu, China, deposited the surprising total of 115 eggs on grubs of *Popillia* spp., and a series of 46 females averaged 54.9 eggs each. The averages for the entire series in China during the three years are shown in Table 3.

TABLE 3.—*Rearing records of Tiphia popilliavora obtained at Penniu, China, 1925–27*

Year	Females in tests	Eggs laid	Average per female	Cocoons formed	Ratio of cocoons to ovipositions
	Number	*Number*	*Number*	*Number*	*Percent*
1925	482	11,307	23.5	7,794	68.9
1926	466	13,071	28.4	7,738	59.2
1927	513	15,799	30.8	9,306	58.9

It will be seen that the average number of eggs per female ranged from 23.5 to 30.8, as contrasted with less than 15 for the Japanese race. In the percentage of cocoons formed from the total of ovipositions the records are 41 percent for Japan in 1922, 21.4 and 25 percent for two series in Chosen in 1925, and, contrasted therewith, 58.9 to 68.9 percent of the much greater oviposition totals in China, under similar rearing conditions.

It is evident that the Chinese race of *Tiphia popilliavora* has nearly double the reproductive capacity of those in Japan and Chosen, and considerably in excess of the generally accepted average for the genus. In the percentage of ovipositions which yielded cocoons is found also an indication of greater adaptability in overcoming adverse environmental conditions.

In view of the apparent superiority of the Chinese race in fecundity and growth it might be expected that the field parasitization of the host species would be correspondingly greater. This, however, does not appear to be the case. The Japanese race at Koiwai, though of limited range, was found to effect a parasitization of approximately 20 percent of the host-grub population each year, whereas in Chosen, in 1925, the parasitization in a relatively small number of grubs brought in was 10 percent, this representing the maximum noted for that section during the course of the investigations. At Penniu, China, the field parasitization was found to be only 3.5 percent in 1926, as determined by an examination of over 15,000 grubs brought in during the course of the breeding work. Although the foregoing figures do not fully represent the field effectiveness of the species, owing to the fact that a portion of the collections were made early in the oviposition period, yet the conditions were very nearly similar in the various fields, and the percentages given are felt to represent closely the relative extent of parasitization achieved.

As an illustration of the effect of temperature on the development of the early stages of Tiphia, the data at hand regarding *T. popilliavora* in its various localities may be cited. At Koiwai, Japan, in late August and early September the egg stage covered 8 days and the larval stage, to the formation of the cocoon, 18 to 30 days, whereas at Yokohama these were 4 and 14 days, respectively, with a maximum temperature range during the period of development of 80° to 97° F. In Chosen in early September this was further reduced to 3, and 11 to 12 days, respectively, under high-temperature conditions. At Penniu, China, the combined egg and larval stages covered 22 to 24 days at normal temperatures, while in a heated laboratory at from 60° to 70° only 15 days was required.

SHIPMENTS

Very extensive shipments of reared cocoons of *T. popilliavora* were made from Japan in 1920 to 1923, and from China in 1925 to 1927, inclusive, and a very small number also from Chosen. The shipments of recent years have been utilized to strengthen the already-established colonies in New Jersey and to extend the distribution to the outlying areas of the beetle infestation. In 1925 and 1926 consignments of adult females were also forwarded, but the percentage alive on arrival was exceedingly low, as compared with that secured with those species emerging in the spring and early summer.

During the period from 1920 to 1928, inclusive, 2,249 adult females were shipped from Japan, and 30,134 cocoons from Japan, Chosen, and China. Approximately 25,000 of the latter were from southern China.

TIPHIA VERNALIS ROH.

GENERAL OBSERVATIONS

The life history and general habits of *Tiphia vernalis* have been fully treated in the previous publication (*6*), but additional data are now available regarding its distribution and host relationships.

Through the determination of miscellaneous material collected in the field the species is known to occur in small numbers at Yokohama and Asakawa, Japan, and at Kuling, Zehsah, Hangchow, and Zakow, China, in addition to the original locality of discovery at Suigen, Chosen. The range of distribution is thus comparable to that of *Tiphia popilliavora*, as is also the marked localization of the infestations.

The original finding of this species in Chosen indicated its normal host in that country to be *Popillia castanoptera*. The few individuals collected in Japan in 1920 and 1921, now determined as *Tiphia vernalis*, were at that time tested upon *P. japonica* and found to parasitize it readily, but the very small numbers available prevented any further work being done on them. In view of the fact that *P. japonica* is the only representative of the genus occurring in the localities in which the Tiphia specimens were collected, it may be assumed with some certainty that this is the normal host in Japan. In China the species known to be attacked are *P. chinensis* and several others of the genus. Under field conditions in 1923, 1924, and 1925 in Chosen *T. vernalis* was found to parasitize approximately 10, 6, and 10 percent, respectively, of the grubs of the preferred host, *P. castanoptera*.

LIFE-HISTORY NOTES

In Chosen the duration of the egg and larval stages, to the formation of the cocoon, was found to be 7 to 13 days and 20 to 25 days, respectively, dependent upon temperatures, which vary greatly from the time the adults first appear in early May until the completion of development of the larvae in early July. From eggs secured at Zakow, China, in late April and early May, 1926, it was determined that the two stages covered 9 and 10 days, respectively, in that section—a very appreciable difference from that given for Chosen and one which may be attributed to very high temperatures prevailing during the period of development of the larvae.

The daily oviposition rate of *T. vernalis* in the breeding cages is relatively low, averaging slightly less than 0.5 egg per day per female

over a period of about 1 month, as compared with the 1.5 eggs per day of *T. popilliavora* during a period of approximately 3 weeks. In the production of cocoons the yearly average ranged from 40.6 percent of the ovipositions in Chosen in 1923 to 56.6 percent for a small lot in China in 1926.

SHIPMENTS

During the years 1924 to 1927, inclusive, 21,455 cocoons of *Tiphia vernalis* were reared and shipped from Chosen and 234 from China, and from 1926 to 1928 the shipments of adult females from Chosen totaled 21,442. The much greater success resulting from the forwarding of adults rather than cocoons has led to the abandonment altogether of breeding work on this species.

In the shipment of adults of this species it was found that the highest percentages of survival were secured in those consignments which had been collected soon after the emergence of the wasps, when they had mated and become fully fed on their normal food, yet had not accomplished any extensive oviposition. The survival figures for the various shipments are given in table 4.

TABLE 4.—*Survival of adults of Tiphia vernalis during shipment from Chosen to the United States, 1926–28*

Year	Shipment	Adults shipped	Adults surviving shipment	
		Number	*Number*	*Percent*
1926	First shipment	990	99	10.0
	Second shipment	1,535	43	2.8
	Third shipment	1,800	312	17.3
1927	First shipment	3,581	2,841	79.3
	Second shipment	6,284	2,370	37.7
1928	First shipment	3,208	1,396	42.3
	Second shipment	3,051	159	4.0
Total or average		21,442	7,220	33.7

TIPHIA MATURA A. AND J.

GENERAL OBSERVATIONS

The first of the natural enemies of Popillia to be encountered in India was *Tiphia matura*, which was found in varying numbers in the Khasi Hills of Assam in the district surrounding Shillong, at an elevation of 4,800 to 6,400 feet. Its normal hosts are the several spring and early summer species of Popillia, principally *P. cupricollis*.

During May and June, 1925, grubs were frequently brought in which bore Tiphia eggs ventrally between the penultimate and last segments of the abdomen, but very few females of species with the habit of placing the egg in this position could be found; in fact, only seven were collected during this first season.

As investigations in 1926 and 1927 revealed new collection areas, an ample supply of females was available for the breeding work. The areas where these were found in numbers were widely separated and apparently determined primarily by the food supply, this consisting of the fluids voided by aphids and other bugs. On the other hand, the more extensive breeding areas were in sparsely planted pine forests in which the branches of the trees up to about 20 feet had been removed,

and the undergrowth was light, owing to its being cut each year. The soil in these localities is very gravelly and well drained. A maximum field parasitization of about 20 percent was observed, based on a count of grubs bearing eggs or larvae, and of fresh cocoons in the soil.

The wide separation of the breeding and feeding areas of this species is in contrast to the condition existing with respect to the other species of the genus which have been studied, as it had previously been concluded that the flight capabilities of Tiphia in general were relatively limited. The number of parasitized grubs in the soil in the areas where the host grubs occurred in abundance was out of all proportion to the number of Tiphia females which could be found there. These main breeding grounds of the beetle were situated at an elevation of from 5,000 to 5,200 feet in very hilly country, and were bordered on one side by a range of heavily forested hills rising to an elevation of 6,400 feet. It was only after extensive scouting that the feeding grounds of the parasite were found, and these were finally located at the crest of the range of hills several miles away, and at the border between the forested area and the largely uncultivated plateau district beyond. At the margin of the forest was a considerable growth of shrubs of various kinds heavily infested with aphids. Here the Tiphia congregated from 8 to 11 o'clock each morning in large numbers, and it was possible to collect several hundred on a single small bush.

The uncultivated plateau area previously mentioned appeared to be an ideal locality for the development of Popillia itself, and it was at first thought that the Tiphia collected at the border were attacking grubs in the immediate vicinity. A search during several seasons, however, failed to reveal more than an occasional individual of any host species in this locality, or in any other nearer than the pine forests in which the parasitized grubs had previously been found in numbers. It appears surprising, in view of the known habits of other members of the genus, for the females to travel through several miles of forest to an elevation nearly 1,000 feet higher for feeding and then to return for oviposition, but extended observations through several seasons substantiate the conclusion that these are the facts in the case.

LIFE HISTORY

There is a single generation of *Tiphia matura* each year, and the winter is passed in the adult stage within the cocoon in the soil. In the 1927 shipment of cocoons, arriving at Riverton, N.J., November 7, a considerable number of adults had emerged en route, and in the field a few may be found during the fall months of the warmer years. This species is evidently one which, under slightly more favorable climatic conditions, would produce two full generations each year.

The seasonal occurrence of the adults is dependent to a large extent on the time of the first spring rains. In 1927 the first individuals were found in the last week of April, the peak of abundance being attained during the third week in May. In 1928 it was very warm during the early spring, and the first rains fell during the middle of April. As a result the parasite began to emerge very much earlier than in the preceding season, the first females being collected on April 11. They were present in considerable numbers from April 16 to 20, at which time a sex ratio of 25 females to 1 male was noted—an abnormal condition, as with most species the reverse is true during the early

part of the emergence period. After that date a decline set in owing to the cessation of the rains. The proportions of the sexes then became approximately equal. Increased emergence took place from May 1 onward, the peak occurring about May 12, and collection was continued until June 7. The adults were thus present in the field approximately 2 months, a considerably longer period than with the majority of species of Tiphia. It is probable that the long period of life and the relatively slow rate of oviposition are due to the previously discussed habit of traveling long distances for food, which does not permit of daily visits to the breeding grounds.

The egg of this species is placed ventrally on the abdomen in the groove between the eighth and ninth abdominal segments and near the lateral margin. The manner of feeding of the larva, and its development, correspond in all respects to those of other species studied.

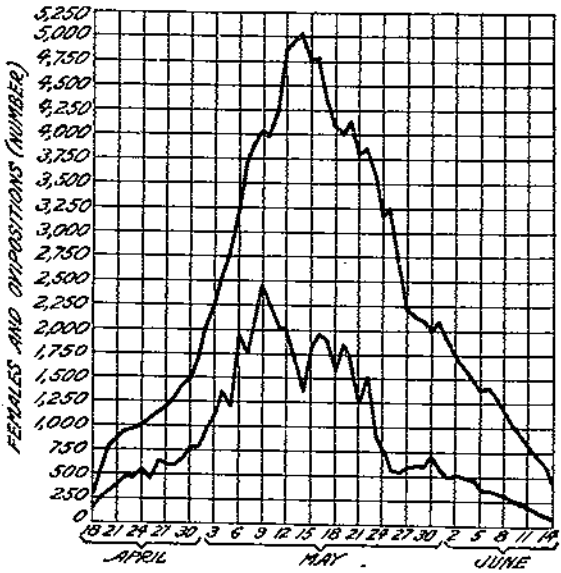

FIGURE 15.—Numbers of females of *Tiphia matura* in the rearing tins (upper curve) and the daily records of ovipositions (lower curve) during the 1928 season.

COLLECTION AND REARING RESULTS

In 1926, the first season in which extensive work was undertaken with this species, 8,005 ovipositions were obtained. These resulted in the formation of 2,712 cocoons, of which 470 were discarded owing to attack by fungus.

From May 5 to June 17, 1927, 12,606 females were collected and from these 44,562 ovipositions were obtained, resulting finally in the production of 13,407 cocoons.

Figure 15 shows the number of females of *Tiphia matura* in the breeding cages each day during the period in 1928 in which they could be secured in numbers in the field, and the daily record of ovipositions obtained from them under laboratory conditions.

The collection work was started on April 13 and continued daily, with the exception of 5 days of heavy rain, until June 7. The maximum number of females in the cages at one time was 5,054 on May 14, which date, or a few days earlier, represented the numerical peak of female abundance in the feeding areas. The greatest number of eggs deposited in a single day was 2,467, from 4,033 females, and the number of ovipositions from 12,518 females during this entire period was 53,897. The general average was 0.39 egg per day per female, as compared with 0.27 in 1926 and 0.4 in 1927.

From these eggs, largely upon *Popillia cupricollis*, there was finally obtained a total of 16,249 cocoons, a percentage of 30.1, the same as in 1927, as compared with 33.9 in 1926.

The methods of rearing *Tiphia matura* in the laboratory were in general the same as those previously employed with various other species in Japan and Chosen, except for modifications in the handling of the grubs following parasitization. The soil available for use in the breeding trays dried out and pulverized very quickly, and the direct application of water to these trays during the development of the Tiphia larvae often resulted in some loss through the collapse of the grub cell. This was prevented by the use of burlap covers over each tray, which were soaked in water at necessary intervals. This moisture seeped down into the soil in a more natural manner and maintained a higher and more favorable humidity as well.

The unsatisfactory physical condition of the soil, however, led finally to the use of freshly chopped moss as a substitute, with a resultant increase of 10 to 15 percent in the yield of cocoons.

SHIPPING METHODS

The cocoons were permitted to remain in the original cells in the breeding trays until the time for shipment, when they were transferred directly to the containers and forwarded. Owing to the long period en route, usually from 40 to 50 days, it was necessary to devise special methods of packing, both to insure an adequate humidity in the cases and to eliminate so far as possible the spread of fungous infection from one cocoon to another.

During the earlier investigations on this and other species it had been believed that the fungus present was developing on the bodies of dead larvae only, but later its true pathogenic nature was established. In transferring cocoons it consequently became necessary to employ frequently sterilized forceps to prevent the spread of spores by contact, and to separate the cocoons more widely in the shipping containers.

The earlier consignments were packed in tin containers inclosing heavy paper or celluloid cross-section blocks, of the type used in commercial egg crates, with one cocoon placed in each section. The tins were packed in moss in wooden cases. This maintained the moisture content, but a heavy loss resulted through fungus spreading in the tins.

The shipping containers later employed included wooden trays 15 inches square and 2 inches deep, fitted with cross-section sets providing compartments 1 inch square and 2 inches deep. Two cocoons were placed in each compartment, each cocoon being surrounded with moss, and separated from the other by a square of tin or celluloid. The trays, holding 450 cocoons apiece, were then packed in sets of five, surrounded by a layer of fresh sphagnum moss, in large wooden cases.

This method of shipment resulted in the reduction of loss from fungus to 2.4 percent in a total of 15,750 cocoons forwarded in 1928, as compared with 74 percent loss in the 1927 shipment of 9,300 cocoons. In the latter shipment 426 adults had emerged in the cases prior to arrival at Riverton, which would indicate that the temperature in the cases must have been exceptionally high in transit, as other consignments forwarded at normal temperatures did not show this emergence.

The total shipments of *Tiphia matura* from India during the years 1925 to 1928, inclusive, comprised 27,470 cocoons, practically all of which were reared from field-collected females.

TIPHIA BISECULATA A. AND J.

GENERAL OBSERVATIONS

Tiphia biseculata is normally a parasite of a species of Anomala, but it will develop readily upon *Popillia japonica*. It was first encountered in 1920 and was tested at that time on the latter host, but the percentage of mortality in the egg and early larval stages was so great as compared with other species that it was assumed that this host was unsuitable. It was later discovered, however, that this loss occurred also on the native host under similar conditions, and that development upon Popillia was fully as good as upon Anomala.

Tiphia biseculata has been found to date only in a single locality in Schizuoka-ken, Japan, in a small, sandy peninsula jutting out a few miles into the sea near Shimizu, which has an exceptionally temperate climate as compared with that of the inland areas.

LIFE HISTORY

Owing to the very favorable climatic conditions prevailing in its native habitat *Tiphia biseculata* is able to develop two full generations each year. This and *T. tegitiplaga*, occurring in the same locality, are the only species encountered in Japan and Chosen having this habit. As the soil contains a very high proportion of sand the soil temperatures are relatively high, and insect activity is extended over a longer period during the year.

The adults of the spring generation appear in the field throughout June and those of the second from late August to the end of September or to early October. Hibernation is in the adult stage in the cocoon. The first brood feeds entirely on the honeydew voided by aphids infesting melon vines and other truck crops, whereas the second feeds very largely at the nectar glands found at the base of the leaf petiole of sweetpotato, at the blossoms of buckwheat, and at times extensively upon the secretions of the pine aphid. The first brood is much more numerous than the second.

The egg is laid ventrally in the suture between the third thoracic and the first abdominal segments, with the anterior pole directed toward the lateral margin of the host. This position may vary to a certain extent, some being found one segment farther caudad, and others may be placed in the median suture between the last pair of legs. In the normal position it is not situated so near the lateral margin of the host body as is the egg of certain other species, the anterior pole being usually at the inner base of the hind leg. The host grubs used in the rearing work were *Anomala* spp.

The duration of the egg stage is 4 days in June and 5 in September, and the larval feeding period, to the formation of the cocoon, occupies 18 days in the first generation and approximately one month in the second, owing to the much lower temperatures of late September and October.

The maximum number of eggs secured from a single female of *Tiphia biseculata* in captivity was 38, the average being 19.6 for the

several thousand females in the breeding series, which had an average length of life of 13.1 days. The egg production per day per female was thus comparable to that obtained with *T. popilliavora* at Koiwai (*6*).

REARING METHODS

The methods used with *Tiphia biseculata* were identical with those previously employed with *T. popilliavora* and *T. vernalis*. To eliminate so far as possible the high rate of mortality due to the loss of the lightly attached eggs and early-stage larvae through the movements of the host grubs in the sandy soil available at Miho, a quantity of light loam was secured for use in the breeding tins. As a result of this change the proportion of cocoons obtained from the eggs laid increased from 20.5 percent in 1925 and 20.1 percent in 1926 to 30.3 percent in 1927. This is still a very low figure as compared with those for many of the other species studied, and is very largely due to the comparatively light attachment of the early stages, as previously described. The greater activity of the host grubs in the rearing tins, as compared with that under natural conditions in the field, makes this loss unavoidable.

As the rearing work was done late in the season (early October and November) the normal insectary temperatures were not sufficiently high to bring the larvae to maturity, and it was consequently necessary to provide heated quarters for the rearing trays.

SHIPMENTS

During the years 1924 to 1928, inclusive, 13,033 cocoons of *T. biseculata* were forwarded to the United States, all of which had been reared from females of the second broods. A consignment of 1,000 adult females, forwarded October 4, 1926, and arriving at the Riverton laboratory October 21, showed a survival of 111, or 11.1 percent, but the field temperatures in New Jersey at that time of the year were so low as largely to inhibit activity and oviposition by the parasites. The 1928 shipment of 2,651 adults was from the first brood, and arrived in New Jersey on July 2, after being 19 days en route. Only 106, or 4 percent, were alive, these being among the last collected in the field prior to being forwarded. The very high mortality in this instance was probably due to the high temperatures prevailing during transit across the United States. The season of the year at which the first brood of adults must be forwarded thus makes this method of shipment impracticable, whereas the consignments of the second arrive too late to be of value, consequently the rearing and shipping of cocoons has been the more satisfactory method of dealing with this species.

TIPHIA PULLIVORA A. AND J.

GENERAL OBSERVATIONS

Large numbers of *Tiphia pullivora* have been found in the Khasi Hills of Assam, India, at an elevation of 4,800 to 5,200 feet. The adults appear in the field from late July to early October and feed at various blossoms and nectar glands and on the honeydew from aphids. The principal host under normal field conditions is an undetermined ruteline species of rather small size, while an occasional individual of *Popillia cupricollis*, in the second or early third stage, and another

species of Popillia also, were attacked. The egg is laid ventrally between the second and third abdominal segments with the anterior pole directed toward the lateral margin. In the laboratory a series of females was tested upon half-grown grubs of *P. cupricollis* and found to develop satisfactorily. In view of this it was thought that the species might serve against *P. japonica* in America, particularly on the grubs too small to accommodate properly the other fall species of Tiphia already imported from Japan, Chosen, and China.

Extended experimental work with this species on grubs of *Popillia japonica* in the United States indicates, however, that it is able to develop only with difficulty on this host, and all field colonizations have failed to establish themselves.

The normal host of *Tiphia pullivora* was very abundant in the waste areas in the hills sections, inhabiting fallow agricultural lands, lightly forested hillsides with rather sparse undergrowth, and sod along forest pathways and roads. The field parasitization in some localities was found to range as high as 27 percent—an exceptional condition with Tiphia and unusual in the case of any parasitic insect in Assam.

FIELD COLLECTIONS

Because of the abundance of host grubs and the percentage of parasitization, large numbers of cocoons of *Tiphia pullivora* could be collected in the field, and consequently rearing work for obtaining these was rendered unnecessary. Practically all larvae had spun the cocoon by the middle of October, and collections of these could be made during the following two or three months for winter shipments and in May, June, and early July for forwarding to arrive in the United States just prior to the time of normal emergence.

As the cocoons are very small and delicate, considerable loss occurs through mechanical injury at the time of collection. With a cocoon of this type it is usually difficult, in fact impossible, to detect through external evidence whether such injury has occurred, unless the cocoon is very noticeably crushed. The truer indication is the early development of fungus on the body of the larva and the subsequent envelopment of the cocoon by the mycelium.

During the period of collection the cocoons as soon as found were set aside in trays under as nearly uniform conditions of temperature and humidity as possible. They were then examined at frequent intervals and those showing fungus development discarded to prevent its spread to other cocoons.

A general average of about 100 cocoons per day could be found by each of the collectors, and the number of these employed ranged up to 20 at certain times. Digging was extended over a period of several months each year.

With the cocoons of *Tiphia pullivora* in the field there was intermixed a varying proportion of those of *T. capillata* A. and J. and *T. levipunctata* A. and J. As there was no means by which these could be distinguished, the entire lot was included in the shipments. Separation of adults could be readily made at the time of emergence, as the latter two species are characterized by the reddish coloration of the legs.

SHIPMENTS

The first consignment of these cocoons, comprising 5,300, was forwarded in November 1925, half being placed individually in gelatin capsules and half in paper cross-section sets in tin containers. The

apparent condition of this lot on arrival indicated that 93 percent were alive, and in a following shipment of 8,660 in March 1926, of the same generation, 65 percent were alive. No emergence was secured from this material, however, a portion living through the second winter and then dying. In all of the following winter shipments this tendency to carry over to the second season has been noted.

The summer collections, forwarded so as to arrive in the United States just prior to the emergence of the adults, were always in less satisfactory physical condition than those sent during the winter. The shipments of 1926, which were sent by mail and were 56 to 61 days en route, resulted very unsatisfactorily. In 1928 the date of forwarding the summer shipment was further delayed and cage provision made for emergence en route, an agar preparation being supplied as food. The cages were placed in the vegetable chamber of the steamer from Calcutta, having an approximate temperature of 40° F. About 12 percent of a total of 7,539 emerged en route in spite of the relatively low temperature, but only one of these was alive upon arrival. The remaining cocoons were of doubtful vigor.

Shipments during the summer were finally abandoned and efforts concentrated on those sent during the winter. The increased care in handling, to reduce fungous attack, during collection and storage, in conjunction with the improved methods of storing devised at the Riverton laboratory, have resulted in a fairly adequate emergence of adults from the more recent consignments.

The total number of field-collected cocoons shipped to the United States during the years 1925 to 1928, inclusive, was 93,815, of which a varying proportion were of species other than *Tiphia pullivora*.

Tiphia brevilineata A. and J.

Tiphia brevilineata has thus far been found only in the vicinity of Suigen, Chosen, and in rather limited numbers. It is normally parasitic on the grubs of *Anomala sieversi* Heyd., and *Phyllopertha pubicollis* Waterh., but in the laboratory it was found to oviposit and develop readily upon *Popillia mutans*.

The adults appear in the field throughout July and till the middle of August and feed upon the liquid excretions of aphids and other bugs. One generation is produced each year, and the winter is passed in the larval stage in the cocoon.

The egg is at first translucent white, later taking on a yellowish tinge. It is placed ventrally between the third and fourth abdominal segments of the host grub, near the lateral margin, and with the anterior pole directed outward. Hatching occurs in 3 or 4 days, and the cocoon is spun from 12 to 15 days later under maximum temperature conditions in Chosen. The outer covering of the cocoon forms a distinct envelope.

In 1925, laboratory ovipositions numbering 140 were obtained, from which 75 cocoons developed and were shipped to the United States. Owing to the scarcity of adults in the field in the known collecting areas, it has not been possible to carry on extensive rearing work with this species.

Tiphia notopolita A. and J.

Tiphia notopolita has been found in relatively small numbers in the Provinces of Chekiang, Kiangsu, and Fukien in China, and has also

been taken at Yokohama, Japan, and Suigen, Chosen. Its normal hosts in China are *Popillia chinensis* Friv. and *P. formosana* Arrow.

The adults appear in the field in late August and may be found until the middle of October, this period varying somewhat in the different localities in which the species is found.

The egg is laid ventrally between the eighth and ninth abdominal segments of the host, the anterior pole toward the lateral margin. The duration of the egg and larval stages combined was found to be approximately 20 days at normal temperatures in September and early October, this being reduced to 15 days when the rearing trays were kept in a room heated to from 60° to 70° F.

Owing to the scarcity of adult females and the small percentage of eggs which developed, only 33 cocoons were obtained during the two seasons.

Tiphia communis A. and J.

Like *Tiphia notopolita*, *T. communis* has been found in China in the Provinces of Chekiang, Kiangsu, and Fukien, but in some numbers. In the field it is parasitic upon various ruteline grubs, mainly of *Miridiba trichophorus* Fairm., and experimentally has been found to reproduce readily upon *Popillia formosana*. At Penniu, in 1926, an examination of over 15,000 field-collected Popillia grubs showed a parasitization of 0.57 percent, while 1.15 percent of those of *Autoserica* sp. were found to bear eggs or larvae of this species. At times Adoretus is also a host of this species.

Two generations are produced each year, the adults of the first appearing in the field from the middle of June to the end of July, whereas those of the second are present from early August to the end of September, the peak of numerical abundance of females being July 7 to 19 and September 9 to 21, respectively. At Penniu they persisted in the field until November. The adults of both broods feed at the blossoms of wild carrot and other weeds.

The egg is pure white when laid but assumes a grayish or brownish tinge before hatching. It is placed dorsally between the second and third thoracic segments, with the anterior pole toward the median line.

The egg stage occupies 8.5 days, and 11 or 12 days are required for the development of the larva to the formation of the cocoon. The cocoon stage of the summer generation was found to be 36 days. The incubation period as compared with the larval stage is exceptionally long, particularly in view of the high temperatures prevailing during June in the area of investigation.

In the breeding work in various localities in 1925, 4,155 ovipositions were secured, from which 1,256 cocoons resulted, a percentage of 30.2.

The value of this species as a parasite of *Popillia japonica* in the United States will depend on the effect of the new climatic conditions upon its annual cycle. If these changed conditions result in only a single generation in the early spring, it will be of value; but the retention of its original time of emergence would render the first generation valueless and unable to reproduce itself through the lack of host grubs.

A small consignment of adult females was forwarded in July 1925, but all were dead on arrival; however, during this and the following season 1,480 reared cocoons were shipped.

TIPHIA ASSAMENSIS A. AND J.

TIPHIA CLAUSENI A. AND J.

Two species of Tiphia were found to occur in very small numbers during the spring months in Assam, India, *T. assamensis* and *T. clauseni*. The former is parasitic on the mature grubs of *Popillia cupricollis* and places its egg ventrally between the second and third abdominal segments. *T. clauseni* attacks the grubs of an undetermined species of Popillia. The egg position is dorsal between the second and third thoracic segments. Owing to the very small numbers available, no rearings for shipment could be made.

TIPHIA SP.

Adults of an undetermined species of Tiphia, which were found feeding at the blossoms of various umbelliferous plants, were collected in the field at Taihoku, Taiwan (Formosa), in September 1927. The normal host in the field was not determined, but insectary tests showed that it oviposited and developed very readily upon Popillia grubs, and it is probable that some member of the genus is the true host.

The egg has a yellowish tinge, and is placed ventrally between the seventh and eighth abdominal segments. The egg and larval stages cover 3 or 4 and 12 to 15 days, respectively.

MISCELLANEOUS SCOLIIDAE

In view of the establishment in recent years of infestations of *Anomala orientalis*, *Autoserica castanea*, and *Serica similis* in the eastern part of the United States from the Asiatic regions, it has become necessary to investigate the possibility of effecting the introduction of their natural enemies. In addition to *Tiphia biseculata*, *T. brevilineata*, and *T. koreana*, which have been discussed as possible Popillia parasites, though attacking Anomala under normal conditions, the following species have been studied and shipments made to the United States:

Parasite	Host	Country
Tiphia bicarinata Cameron	Anomala, Phyllopertha	Japan, Chosen, China.
Tiphia totopunctata A. and J.	Anomala, Phyllopertha	Chosen and China.
Tiphia agilis Smith	Serica	Japan, Chosen, China.
Tiphia ovidorsalis A. and J.	Serica	Chosen.
Tiphia asericae A. and J.	Serica	Japan, Chosen, China.
Tiphia notopolita alleni A. and J.	Phyllopertha	Chosen and China.
Tiphia malayana Cameron	Adoretus	China.
	Serica	Chosen.

TIPHIA BICARINATA CAMERON

Tiphia bicarinata was found in very small numbers in Japan and in Fukien, China, but was abundant at Suigen, Chosen. It is a normal parasite of the grubs of *Anomala sieversi* and *Phyllopertha pubicollis* and should prove adaptable to *A. orientalis* in the United States.

The adults appear in the field from early in August to the middle of September and feed at the blossoms of various Umbelliferae. A single generation is produced each year, and the winter is passed in the larval stage within the cocoon,

The egg is pale yellowish and is placed ventrally between the third and fourth abdominal segments of the host grub, or occasionally one segment away in either direction, with the anterior pole directed laterally. The egg and larval periods cover 3 and 12 to 20 days, respectively, under relatively high temperature conditions. The cocoon of this species may be readily distinguished from that of all others of the genus studied by its glazed outer surface and by the almost complete lack of the web of silken strands which usually surrounds cocoons of Tiphia.

Although with most species of Tiphia a second oviposition on a grub already parasitized results in the loss or breakage of the first egg laid, this does not necessarily take place with *T. bicarinata*. Very frequently grubs have been found in the field bearing 2 or 3 eggs, and one was observed with 6. Also it has been noted that 2 larvae will develop side by side on the same host grub and eventually spin normal cocoons. With other species the result in such cases is usually the death of both larvae. Under laboratory conditions a maximum of 6 eggs was laid in 1 day by a single female.

In 1925, 1,200 ovipositions resulted in 726 cocoons, giving the exceptional percentage of 60.5 developing to that stage. The 1926 breeding work resulted in 9,982 eggs, from which 5,824 cocoons, or 58.3 percent, were secured. Shipments of reared cocoons to the United States to the end of 1928 totaled 5,720.

Tiphia totopunctata A. and J.

One of the species which was secured in relatively small numbers at Suigen, Chosen, in 1925 and 1926 was *Tiphia totopunctata*. It is recorded also from Szechuen, China. It is parasitic upon the grubs of *Anomala sieversi* and *Phyllopertha pubicollis*.

The adults may be found in the field from the early part of July to the latter part of August feeding upon the honeydew of aphids and other bugs. There is a single generation each year, and hibernation is in the mature larval stage.

The egg is dark brown and is placed dorsally on the third thoracic segment, with the anterior pole toward the median line. Under fairly high temperature conditions the incubation period is 5 or 6 days, and the development of the larva to the spinning of the cocoon requires 18 to 20 days. The outer covering of the cocoon forms a distinct envelope readily separable from the cocoon itself.

Owing to the scarcity of adults, only 245 ovipositions were secured in 1925, of which 35 developed to the cocoon stage. In 1926, material was somewhat more abundant, and 1,307 ovipositions yielded 605 cocoons, a development percentage of 46.3. Of these cocoons, 446 were shipped to the United States for colonization.

In view of the late appearance of the adults in the field, it is questionable whether this species will be of value against *Anomala orientalis* in the United States, as the time of their appearance very nearly coincides with the emergence of the beetles in the infested section.

Tiphia agilis Smith

Tiphia agilis was found most commonly at Suigen, Chosen, but has also been taken in various localities in central Japan and at Kuliang, China. It is parasitic upon *Serica orientalis* Motsch. and others of that genus which are in the mature larval stage late in the summer.

The adults appear in the field about the middle of July and persist until the latter part of August. They feed on the honeydew of aphids occurring upon various species of oak, and at a variety of blossoms.

The egg, which is dark in color, is laid ventrally between the third and fourth abdominal segments of the host, with the anterior pole directed toward the lateral margin. Hatching occurs in 3 or 4 days, and the larval feeding period is complete in 12 or 13 days at summer temperatures. The cocoon is of normal form and color, with the outer covering loose and not separable into layers.

From 178 eggs obtained in 1925 during the breeding work 122 cocoons were eventually formed, giving the exceptional development percentage of 68.5. Total shipments during that and the following year comprised 197 cocoons.

Tiphia ovidorsalis A. and J.

A species parasitic on *Serica* sp. at Suigen, Chosen, *Tiphia ovidorsalis*, has not been noted in any of the other localities of investigation. The adults may be found in the field during August, and feed at the secretions of aphids and other bugs.

The grayish egg is placed dorsally on the third thoracic segment of the host grub, with the anterior pole directed toward the median line. Incubation requires 3 or 4 days and the larval feeding stage 11 to 14 days.

Owing to the limited numbers of females available in the field, extensive insectary rearings were not possible. In 1925 and 1926 only 99 cocoons were secured for shipment to the United States.

Tiphia asericae A. and J.

Tiphia asericae has been recorded from Iwateken, Japan, Keikido, Chosen, and Chekiang, China, and was by far the most abundant in the Chosen area. It is parasitic on various species of sericine grubs which attain maturity during the late summer and fall.

The adults appear in the field in Chosen early in June and persist to the end of that month or the first part of July. Feeding occurs on the honeydew given off by aphids and other bugs infesting pine, oak, and chestnut trees.

The egg is laid laterally in the suture between the seventh and eighth abdominal segments, just above the spiracle of the eighth segment, with the anterior pole directed toward the median dorsal line of the host. The incubation period covers 3 days, and the larva completes feeding and spins the cocoon from 10 to 12 days later, this being under the high-temperature conditions prevailing during June in Chosen. The winter is passed in the adult stage in the cocoon.

In the rearing work conducted at Suigen in 1927, 2,911 ovipositions were secured during the 11 days which could be devoted to this parasite. From these there finally resulted 947 cocoons, a percentage of 32.5, and of these 935 were forwarded to the United States.

Two shipments of adult females, totaling 9,604, were forwarded during the middle of June, 1928. Only 58 out of the 2,527 in the first consignment arrived alive, while none of the second lot survived. This result was in conformity with that secured with other species forwarded at the same season, indicating that the high mortality was due probably to the high temperatures prevailing during the period of transit across the United States rather than to faulty methods of

shipment. Laboratory experiments and field observations also indicate that this species has a shorter normal adult life than is usual in the genus.

TIPHIA NOTOPOLITA ALLENI ROBERTS (T. NOTOPOLITA INTERMEDIA A. AND J.)

The variety *Tiphia notopolita alleni* (*14*) was found in relatively small numbers at Suigen, Chosen, in 1924 and 1925, and is recorded also from Penniu, Hangchow, and Kuliang, China. In Chosen it is parasitic primarily on *Phyllopertha conspurcata* Har., and some individuals attack *P. pallidipennis* Reitt. The adults appear in the field during the latter part of August and persist until the end of September. They feed very largely at the blossoms of Seseli.

The egg is placed ventrally between the seventh and eighth abdominal segments of the host grub, in the depressed area near the lateral margin, with the anterior pole directed outward. The duration of the egg stage is 4 or 5 days and that of the larval stage 15 to 17 days under September temperatures.

Owing to the scarcity of adults in the field, very little rearing work could be accomplished. Only 120 ovipositions were obtained, resulting in 42 cocoons, which were shipped to the United States.

TIPHIA MALAYANA CAMERON

The distribution of *Tiphia malayana*, as determined in these investigations, includes the Provinces of Fukien, Chekiang, and Kiangsu in China, the greatest numbers being found at Zakow. It was found also at Suigen, Chosen.

There is a marked difference in a number of points in the life history and habits of the Chosenese and Chinese forms, and consequently they will be dealt with separately. From the biological data presented it would appear that two distinct species are involved.

The Chinese form is parasitic upon the grubs of *Adoretus* sp., but oviposits and develops readily upon *Popillia chinensis* also. The period of emergence of the adult wasps appears to be unusually protracted, as they are found in the field from the middle of April until August, the greatest numbers being present during the early part of May. The normal period, however, was determined as being from the middle of April to the end of May. The egg is gray and is laid between the second and third thoracic segments ventrally, with the anterior pole toward the lateral margin. The duration of the egg and larval stages is 8 and 20 days, respectively. A maximum of 24 eggs was obtained from one female in the breeding series; and from the 699 ovipositions obtained, mainly upon Adoretus grubs, 320 cocoons were formed, a percentage of 45.8.

In the Chosenese form the adults appear in the field during the latter part of April and are present until the middle of May, this being the first species of the genus to appear in the spring in Chosen. The adults feed largely on aphid honeydew and also at the blossoms of *Forsythia* sp. A single generation is produced each year, and the winter is passed in the adult stage in the cocoon. This form is parasitic on the grubs of various sericine species which are in the mature stage during the spring. The egg is white when first laid but assumes an amber tint before hatching. It is placed ventrally between the third and fourth abdominal segments of the host grub, with the

anterior pole directed outward. The egg and larval stages cover 10 or 11 and 20 to 22 days, respectively, during the latter part of May. The cocoon is intermediate in color, and the outer covering is loose and not separated into layers.

SHIPMENTS

Of the Chinese form, 290 cocoons and 424 adult females were forwarded to the United States in 1925. Of the latter number, 32 arrived alive. The following season 792 females were shipped, of which 118 survived. No material was forwarded from Chosen.

REARING AND SHIPPING OF SCOLIIDAE

The methods of rearing Scoliidae in large numbers have been discussed in general in the preceding bulletin (*6*) on this subject. Certain slight modifications have been found necessary for some species, though these have been required to overcome temperature and soil conditions existing in the particular localities rather than from a difference in the requirements of the species themselves.

In table 5 is given a summary of the rearing results obtained with the different species of Tiphia which have been studied during the course of these investigations. Among those species with which extensive rearings were undertaken the average cocoon production, as based upon the total ovipositions, ranged from 25.9 percent in the case of the second generation of *T. biseculata* in Japan to 61.8 percent for *T. popilliavora* in China. In contrast to the latter record is the 33.5 percent obtained with the same species in Japan.

TABLE 5.—*Rearing results with various species of Tiphia*

Species	Country	Year	Ovipositions	Cocoons produced	Ratio of cocoons to ovipositions	
					By year	By species and source
			Number	*Number*	*Percent*	*Percent*
T. agilis	Chosen	1925	178	122	68.5	68.5
T. asericae	do	1927	2,911	947	32.5	32.5
T. bicarinata	do	1925	1,200	726	60.5	58.6
		1926	9,952	5,824	58.3	
T. biseculata (second generation)	Japan	1925	5,048	1,034	20.5	25.9
		1926	8,756	1,760	20.1	
		1927	18,069	5,474	30.3	
T. brevilineata	Chosen	1925	140	75	53.6	53.6
T. communis	China	1925	4,155	1,256	30.2	31.5
		1926	549	224	40.8	
T. malayana	do	1925	699	320	45.8	45.8
T. matura	India	1926	8,005	2,712	33.9	30.4
		1927	44,562	13,407	30.1	
		1928	53,897	16,249	30.1	
T. phyllophagae	China	1925	2,118	864	40.8	40.8
T. popilliavora	Japan	1920–1922	[1] 10,000	3,350	33.5	33.5
	China	1925	11,307	7,794	68.9	61.8
		1926	13,071	7,738	59.2	
		1927	15,799	9,306	58.9	
T. tolopunctata	Chosen	1925	245	35	14.3	41.2
		1926	1,307	605	46.3	
T. vernalis	do	1923	5,785	2,350	40.6	47.3
		1924	10,903	5,566	50.8	
		1925	13,530	6,404	47.3	
		1926	18,355	8,255	45.0	
	China	1927	8,580	4,659	52.5	50.6
		1926	440	210	50.6	

[1] Approximate.

Owing to the varying times of the year in which the different species of Tiphia occur in the field, it has been necessary to modify the manner of shipment with different species to accomplish successful importation of these parasites. The methods described below are those employed in the work in Japan and China, from which countries the time in transit ranged from 14 to 26 days. The manner of dealing with the Indian species, for which the shipping time extends to 40 or 50 days or even more, has been given in the discussion of the respective species.

SHIPPING COCOONS

It has been found necessary to reduce to a minimum the handling of cocoons prior to shipment to prevent infection by fungous diseases, and also to insure against the spread of these diseases among the cocoons during the period they must be in the shipping containers. Practically all shipments of cocoons are forwarded as soon as the last larvae in the rearing trays have matured. They are then from 2 to 4 weeks in transit to the United States and upon arrival at the laboratory are placed in the storage chamber for hibernation and for keeping until emergence the following season. The test applied for the determination of the physical condition of these consignments upon arrival was the opening of a series of cocoons and the noting of the general appearance of the larvae or other stages contained therein. If the decline in vitality is relatively far advanced the body becomes flaccid, the normal glistening integument becomes dulled, and the body contents assume a somewhat yellowish tinge.

In the shipments from Japan and China in 1925 and later two general methods of packing were employed. The first was the use of individual tin containers, much like the common salve boxes, of slightly less than 1 cubic inch capacity, in which the cocoon was placed, surrounded by a small quantity of slightly moist moss. The tins were then packed in moss in tight wooden boxes.

The second type of container used consisted of tin or wooden cross-section sets in which each compartment had the same volume as the above-mentioned individual tin. The cocoons were individually surrounded by moss in these sections, and the sets were separated from each other by tin sheets.

With both of these forms of shipping containers the physical condition of the immature stages in the cocoons at the time of arrival was good. The individual tins, however, present the one advantage of checking the spread of fungus in the event that too much moisture in the cases should induce its development.

SHIPPING ADULT FEMALES

In the extensive program for the shipment of adult females of *Campsomeris annulata* and the various species of Tiphia from Japan, Chosen, and China from 1926 to 1928 a variety of food materials were tested for keeping the wasps alive en route. The liquids provided in the shipping tins fulfilled two purposes, that of supplying food for the insects and that of maintaining a proper degree of humidity. It was essential that this food should remain in good condition throughout the time in transit, without fermenting or hardening.

In the early shipments the food was combined with the water in a weak solution, the ingredients being either sugar or honey. Later a semisolid food was used, with greatly improved results. This con-

sisted of Japanese agar mixed with either liquid honey or sugar sirup in equal proportions. This mixture is liquid when heated slightly and cools into a semisolid of the consistency of soft rubber. It is poured when warm into tin-lined holes in blocks of wood wired to the inside of the container.

In figure 16 is shown a section of the container used successfully for shipping both Campsomeris and Tiphia. This tin is 6 inches in diameter and 10 inches high, with holes punched in the bottom for drainage.

In the bottom of the tin is first placed a half-inch layer of sphagnum moss, then about 2 inches of moist humous soil, and this is covered with another layer of sphagnum moss, over which is fixed a woven-wire screen of half-inch mesh to prevent the displacement of the soil in case the container is overturned. The bottle contains pure water only, and the lamp wick which leads up through the neck is surrounded by, and rolled into, a rather large mass of absorbent cotton, the whole being then covered with gauze and firmly tied. This provides a large absorption mass and an extensive surface area from which the wasps may drink without becoming entangled in the cotton, and guards largely against spilling. The top of the tin is covered with cloth, securely tied, or may be of perforated metal. The tins are packed in pairs in slatted screen cases.

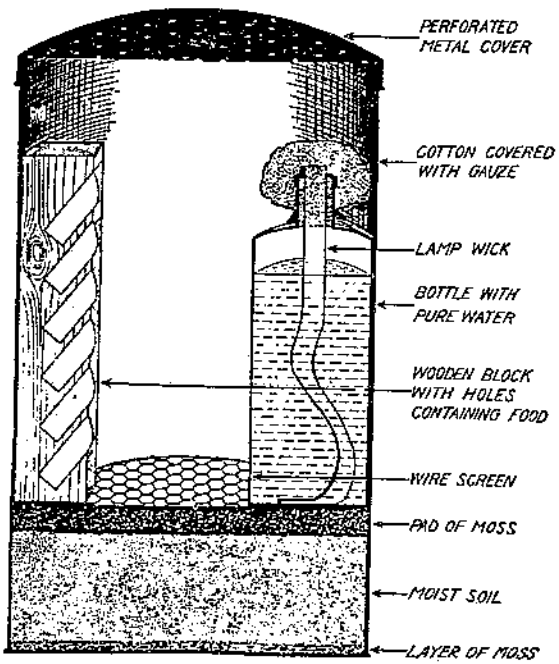

FIGURE 16.—Shipping container for adult Scoliidae, showing details of construction and contents.

The provision of soil in the containers is very desirable, as the wasps like to burrow about in it as they would under natural conditions. Moss alone does not give nearly so satisfactory results.

In table 6 are listed the various species of Scoliidae which have been shipped as adult females, with the period of collection and shipment, the numbers forwarded, and the percentage of survival. With Tiphia it is seen that in general the best results were secured with the spring species and that a very low proportion of those forwarded during the summer and fall were alive upon arrival.

With the majority of species, the shipment of adults rather than cocoons is much more satisfactory, both on the basis of cost and on that of results secured, provided the time in transit does not exceed 30 days.

TABLE 6.—*Shipments of adult Scoliidae, 1925–28*

Species	Country	Period	Shipped	Survival	
			Number	*Number*	*Percent*
Campsomeris annulata	China-Japan	May–November	31,060	4,219	13.6
Tiphia asericae	Chosen	June-July	9,504	58	0.6
Tiphia biseculata:					
Spring generation	Japan	do	2,651	106	4.0
Fall generation	do	October	1,000	111	11.1
Tiphia communis	China	July-August	107	0	.0
Tiphia malayana	do	May–June	1,216	149	12.2
Tiphia popilliavora	Japan	August-September	2,249	65	2.9
Tiphia vernalis	Chosen	May–June	21,442	6,549	30.5

NATURAL ENEMIES OF THE SCOLIIDAE

A varied series of insect species has been found to prey on the immature stage of the Scoliidae, being either parasitic upon these stages within the cocoon or predacious upon the adult wasps. The more extensive records in regard to these enemies have been obtained in India, this being due to the much greater opportunities for the collection of cocoons in the field in that country than was the case in Japan, Chosen, or China.

In Chosen the sphecid wasp *Palarus saishiuensis* Okamoto (*15*) stores its nests with the adults, largely females of various species of Tiphia, occurring in the field during August and September, and to a lesser extent with other Hymenoptera of similar size. The restricted habitat of this hunting wasp is such as to prevent its being a serious enemy over any large area, though the fact that each cell is stocked with from 7 to 14 adults, representing usually a single day's collection, may result in a material reduction in the Tiphia population in the localities suited to its development.

Two species of mutillid wasps, *Mutilla stephani* Magr. and *Mutilla* sp., near *antennata* Sm., were reared from the cocoons of *Tiphia matura* and others in India, but only in very small numbers.

An interesting record from the same locality is that of a species of Perilampus as an occasional parasite in the cocoons of *Tiphia pullivora*. Each year a few adults of this species emerged from the many thousand cocoons collected for shipment to the United States. The planidium in some way, possibly after the cocoon is formed, gains access to the mature larva, to which it attaches itself externally, and development is completed upon the pupa.

A single species of rhipiphorid beetle, *Macrosaigon pusillum* Gerst., was reared from the cocoons of *Tiphia matura* and *T. pullivora*. Some collections of the latter species showed a maximum parasitization of 28.4 percent. The host is killed in the mature larval stage. The adults of this rhipiphorid show three color phases, some being entirely black whereas others have a red thorax or both thorax and abdomen red.

The bombyliid flies are common parasites of scoliid larvae. Three species, *Exoprosopa sipho* Ald., *Aphoebantus clauseni* Ald., and *A. seriatus* Ald., were reared in small numbers from the cocoons of *Tiphia pullivora*. An extended account has recently been published by the senior author (*5*) on the biology of a related species, *Hyperalonia oenomaus* Rond. The first-instar larva of the parasite gains access to the mature larva of the host in the cocoon, and development

is completed upon that stage. This species was also observed to develop occasionally upon larvae of Scolia and Campsomeris.

The nematode *Eomermis tenuissima* Cobb was reared on several occasions from field-collected cocoons of *Tiphia matura* and *T. pullivora*.

SUMMARY OF PARASITE SHIPMENTS TO THE UNITED STATES

In table 7 is given the record of shipments of the various natural enemies of *Popillia japonica* and related species to the United States from the initiation of the project in 1920 to the end of 1928. There is also indicated the stage of development in which the material was forwarded, whether as immature larvae in living hosts, in the cocoon stage or as puparia, or as adult insects.

TABLE 7.—*Record of shipments of parasite material to the United States for the control of the Japanese beetle, 1920–28*

Genera and species	Country	1920	1921	1922	1923	1924	1925	1926	1927	1928	Total
Tachinidae:											
Centeter cinerea, parasitized beetles, dead	Japan	95	118,000	144,000	50,000	50,000			142,000	99,400	603,495
Eutrixopsis javana, parasitized beetles, dead	do			210					78		288
Hamaxia incongrua, field-collected beetles, living	do				6,500	20,700	37,400	25,200	42,100	166,100	298,000
Pyrgotidae:											
Adapsilia flaviseta, puparia	India							6,420	7,601	3,041	17,062
Dexiidae:											
Dexia ventralis, parasitized grubs	Chosen						850	8,624	11,850		21,324
Prosena sibirita—											
Parasitized grubs	Japan		800	7,800						5,000	13,600
Field-collected grubs					11,000	49,000	25,000	25,000	49,000		159,000
Scoliidae:											
Campsomeris annulata—											
Adult females	Japan, Chosen, China						9,190	21,861			31,060
Reared cocoons					4	324	20				348
Parasitized grubs							4,351	2,065			6,416
Tiphia agilis, reared cocoons	Chosen						105	92			197
Tiphia asericae—											
Adult females	do									9,604	9,604
Reared cocoons									935		935
Tiphia bicarinata, reared cocoons	do						720	5,000			5,720
Tiphia biseculata—											
Adult females	Japan							1,000		2,651	3,651
Reared cocoons						98	1,030	1,760	5,323	4,822	13,033
Tiphia brevilineata, reared cocoons	Chosen						75	16			91
Tiphia communis—											
Adult females	China						107				107
Reared cocoons							1,256	224			1,480
Tiphia malayana—											
Adult females	do						424	792			1,216
Reared cocoons							290				290
Tiphia matura, reared cocoons	India						80	2,340	9,300	15,750	27,470
Tiphia notopolita, reared cocoons	China						17	16			33
Tiphia notopolita alleni, reared cocoons	Chosen							42			42
Tiphia ovidorsalis, reared cocoons	do						32	67			99
Tiphia phyllophagae, reared cocoons	Chosen, China						1,409				1,409
Tiphia popilliavora—											
Adult females	Japan, Chosen, China						1,030	1,219			2,249
Reared cocoons		395	905	2,050			7,585	9,135	10,064		30,134
Tiphia pullivora, field collected cocoons	India						13,960	25,417	32,438	22,000	93,815
Tiphia totopunctata, reared cocoons	Chosen						30	446			476
Tiphia vernalis—											
Adult females	Chosen, China							4,325	9,868	7,249	21,442
Reared cocoons						5,348	5,997	6,954	3,156		21,455
Carabidae:											
Craspedonotus tibialis, adult beetles	Japan	1,100	15,350								16,450

AGRICULTURAL AND CLIMATIC CONDITIONS IN CHINA AND INDIA

In the previous publication (*6*) on the natural enemies of *Popillia japonica* in the Far East a short account was given of the agricultural conditions existing in Japan and their relation to the status of the beetle as an economic pest. The conditions in China and India, the new fields of investigation, are different in several respects from those of Japan, and call for some discussion.

The Popillia fauna of China is found largely in the low-lying valley lands of the Yangtze River from Nanking eastward to Shanghai and southward to Hangchow and Ningpo. The hilly areas between Chingkiang and Nanking, the mountainous district beyond Hangchow, as well as the other foothill and mountain sections which were scouted, do not provide suitable breeding grounds for this group of beetles. This is in contrast to the condition found to exist in India, where practically all species of the genus which were at all abundant were found in numbers only at elevations of 4,000 feet or more.

In the valley districts of the coastal Provinces of China intensive agriculture is practiced. Practically all of these districts are irrigated, the land being intersected by a complicated network of canals. Rice is the principal crop grown, with considerable cotton and large plantings of other small grains and various truck crops.

One of the distinctive features of any Chinese landscape is the relatively large area devoted to graveyards. Although these may often be situated on the less arable and rocky hillsides, a considerable portion of the more valuable valley land is taken by them. The burial mounds are usually surrounded by a border of grass 2 or 3 feet in width. This grass is kept closely cropped by cattle, the graveyards being of considerable importance as grazing areas owing to the lack of natural grasslands in these sections. These sod borders provide ideal breeding conditions for Popillia, and it was in such places, in the silt soil along the river and canal embankments, and in the small patches of sod along the paths and roadways that Popillia grubs could be found in numbers.

Of the Popillia fauna of the coastal sections of China, *Popillia chinensis*, *P. mutans*, and *P. formosana* were the most abundant in the valley districts, while *P. pustulata* was abundant in several of the mountain localities in the Provinces of Fukien and Kiangsi. The majority of the Chinese species of the genus appear to be foliage rather than blossom feeders.

The agricultural conditions in India differ markedly from those of Japan and China. The size of the country and its range in latitude, extending from near the Equator to the Himalayas, provide a great diversity in the crops grown and in the methods of cultivation. The plains areas, upon which the vast portion of the population lives, are very intensively cultivated. Throughout practically this whole plains region the annual rainfall is concentrated into a very few months in summer, resulting in an exceedingly arid condition during the winter. The intensive cultivation which is practiced does not permit of the development to numerical abundance of insect pests such as the genus Popillia, which largely inhabit waste lands. Also, the climatic conditions do not favor this genus.

The hill sections of India, found in various parts of the country, particularly in the south, southwest, and northeast, provide a far different condition from that found in the plains, and one more nearly suited to Popillia, to judge from the relatively large number of species which occur in them. These hills range from 3,000 to 7,000 feet in height, and above 3,000 feet are usually covered with grass rather than with the jungle growth which characterizes the lower elevations. Although these hills are inhabited the population is relatively very sparse, and consequently only a very small portion of the land is under cultivation, and a considerable part of that which is arable is used for grazing. The climate is much more temperate, with the rainfall extending over a somewhat greater period than in the plains.

The Khasi Hills of Assam, in which section most of the work upon this project in India was done, attain a maximum elevation of about 6,000 feet. In the zone above 4,800 feet the Popillia fauna was found most abundant, and only occasional individuals could be found below that level. In the upper zone the vegetation is of a distinctively temperate rather than subtropical nature, and the hills are in part covered with pine forests, both natural and planted. The growth of these trees is not very luxuriant, and a light undergrowth of shrubs is usually present. This is induced to a certain extent by the practice of the natives of trimming away the lower branches of the trees for use as firewood. In the case of the cultivated lands the general practice is to permit the land to lie fallow for 1 or 2 years between crops. This fallow land provides an ideal habitat for the development of many scarabaeid species.

Of the 10 or more species of Popillia known to occur in the Khasi Hills, *P. cupricollis* and *P. cyanea* are the dominant forms. Like practically all species of the group, with the conspicuous exception of *P. japonica* and a few others, they confine their feeding almost exclusively to blossoms. The breeding areas of these two species are largely in the sparsely forested areas with a light undergrowth and a gravelly soil, and very few grubs could be found in open grasslands or in cultivated fields, though the adults frequently congregate there for feeding.

Various other sections in addition to the Khasi Hills were scouted for Popillia and its parasites. The Naga Hills in eastern Assam, which appeared to provide as suitable conditions as the Khasi Hills, revealed a very low Popillia population. The Nilgiri Hills in southern India presented more varied conditions than those of Assam, and a considerable number of species of Popillia are on record as occurring there, including one or two which at times become sufficiently abundant to cause injury to cultivated crops. In several trips to that section, however, no parasites were found. In July 1927 several weeks were spent in scouting in Kashmir, largely in the valley region (elevation approximately 5,000 feet) about Srinagar, and also in the near-by foothills to an elevation of 7,500 feet, but not a single representative of the genus was found during this period. It would appear that Kashmir is beyond the western limits of distribution of the Indian species.

Charts showing the monthly mean temperature and rainfall conditions at Sapporo, Koiwai, and Yokohama in Japan and at Suigen, Chosen, appear in the earlier publication (*6*) and those here given for comparative purposes are for Nanking, China, and Shillong, India.

The collection and rearing of parasites in China took place at several widely separated points, but the Nanking conditions are taken as representative of the coastal belt in general.

The temperature curve (fig. 17) shows that Nanking (lat. 32 N.), though much farther south, has winter temperatures slightly lower than those of Yokohama (lat. 35.5 N.), and summer temperaturse slightly higher. The maximum monthly rainfall occurs in June and July, and the peak of the curve is considerably below that of Yokohama or Suigen (lat. 37 N.) and the annual total considerably less than that of either of the other two points mentioned.

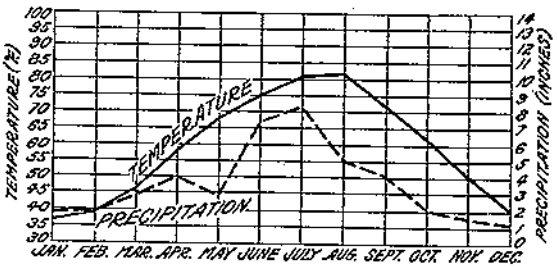

FIGURE 17.—Monthly mean temperature and average rainfall at Nanking, China, 1905–23.

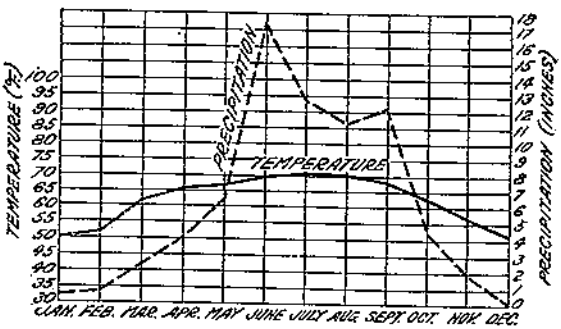

FIGURE 18.—Monthly mean temperature and average rainfall at Shillong, India, 1920–24.

The temperature curve for Shillong, India (lat. 25.5 N.) (fig. 18), differs from those of the other localities studied in that the winter temperature is considerably higher and that of the summer lower. The maximum rainfall is attained rather abruptly in June, and the precipitation during the following three months is fairly heavy, the annual total approximating that at Yokohama. With respect to minimum temperature and time of general rainfall, Shillong and Nanking conditions more nearly approach those of Yokohama than do those of any of the other fields of investigation.

In considering the temperature records for Shillong it is necessary to make allowance for the difference in interval between recordings. Here the monthly mean is based on the averages of three readings per day, at 9 a.m., 3 p.m., and 9 p.m., respectively, rather than the usual 2-hour intervals. On the latter basis the mean temperature would probably be slightly lower than that shown.

SUMMARY

The investigations, previously confined to Japan and Chosen (Korea), on the natural enemies of *Popillia japonica* have been extended to China and India.

Seven species of parasites have been found to attack *P. japonica* itself under natural conditions in Japan. Nine additional species have been found to parasitize different species of Popillia in the other

countries named and are adaptable to *P. japonica*. Of these 16 species, 5 species of Tachinidae and 1 of Pyrgotidae are parasitic in the adult beetle itself, 2 Dexiidae are internal parasites of the grubs in the soil, and 8 Scoliidae are parasitic externally on the same stage.

Among the Tachinidae, *Centeter cinerea* has maintained its status as a major limiting factor in the control of the beetle in northern Japan. The very extensive collections of parasitized beetles in the Sapporo section during the past 8 years have not appreciably reduced its effectiveness in that area. The southern limits of the distribution of the species are now known to extend to the Tokyo-Yokohama district.

Hamaxia incongrua (*Ochromeigenia ormioides*) has been found in numerous additional localities in central Japan, but with the percentage of parasitization exceedingly variable. Its favored habitat is much more restricted than that of the host, it being adapted largely to semiforested areas and waste land covered with a growth of shrubs, rather than to the cultivated fields.

Eutrixopsis javana, *Pexomyia genalis*, and *Trophops clauseni* have been found in exceedingly small numbers in Japan only, and are of no value in the natural control of the host in its native habitat.

Adapsilia flaviseta, the single pyrgotid species found to attack adult Popillia, occurs in the hill sections of Assam, India. Except in occasional very limited areas the extent of parasitization of the host is very slight. All factors in its biology indicate its potential value in the biological control of *P. japonica* to be very low. Its time of attack of the host is delayed and the period of larval development prior to the death of the host is relatively long, thus permitting extensive oviposition. The greater proportion of eggs are laid in male beetles.

Of the two dexiid species, *Prosena sibirita* has been found in the field from the early part of April till the end of September. It is of general distribution in the Asiatic and Malayan regions, but only in northern Japan is it of value against Popillia. *Dexia ventralis* has been found to have three generations each year when overwintering in Miridiba grubs and only two when that period is passed in Popillia. Both species have demonstrated the ability to develop to maturity in only partly mature grubs, though this is not the normal condition.

Among the eight species of Scoliidae parasitic upon the grubs of various species of Popillia, none has been found to have a uniform distribution comparable to that of its host; a high degree of parasitization is seldom found, and then only in very restricted areas. *Tiphia popilliavora* in Japan, *T. vernalis* in Chosen, and *T. matura* in India have shown the greatest field effectiveness in their native habitats. The eventual value of this group of parasites in the United States lies in the possiblity of having a series of these species rather than any single one of them. The food supply of the adults is one of the most important factors affecting increase and distribution.

Five additional species of Scoliidae, comprising *Campsomeris annulata* and four species of Tiphia, have been found adaptable to Popillia in the absence of the normal hosts, which are various species of Anomala.

Owing to the recent establishment of *Anomala orientalis*, *Autoserica castanea*, and *Serica similis* in the eastern part of the United States, studies of their natural enemies have been undertaken in Japan and Chosen.

During the years 1920 to 1928, inclusive, extensive shipments were made of many species of parasites. Among these, 603,495 beetles parasitized by *Centeter cinerea* were collected and shipped, of which about 90 percent contained puparia, while 298,000 live *Popillia japonica* beetles containing a variable percentage of *Hamaxia incongrua* were forwarded, both species from Japan, and also 17,662 puparia of *Adapsilia flaviseta* from India. Of the Dexiidae, 21,324 grubs parasitized by *Dexia ventralis* were shipped from Chosen, and 13,600 parasitized by *Prosena sibirita*, as well as 159,000 field-collected grubs having an average parasite content of about 10 percent, were sent from Japan. Shipments of 17 species of Scoliidae have been made from Japan, Chosen, China, and India, comprising 69,334 adult wasps, 103,212 reared cocoons, 93,815 field-collected cocoons, and 6,416 parasitized grubs.

In the importation of scoliid parasites it has been found that, with the majority of species, the shipment of adults rather than cocoons is much more satisfactory, both on the basis of cost and of results secured, provided the time in transit does not exceed 30 days.

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