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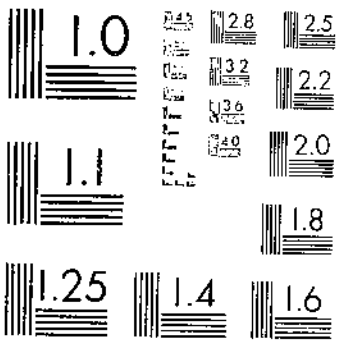
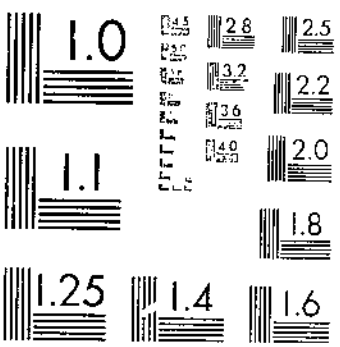


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A



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BIOLOGY OF BRACHYMERIA FONSCOLOMBEI (DUFOUR), A HYMENOPTEROUS PARASITE OF BLOWFLY LARVAE

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INTRODUCTION

Brachymeria fonscolombei (Dufour), a hymenopterous parasite of Diptera, has been known as a parasite of blowflies for nearly a hundred years. Recently it has come under consideration because of the frequency with which it is reared from blowfly larvae. It is the purpose of this bulletin to discuss the biology and behavior of this parasite, with detailed reference to its preferred hosts. These experiments were begun at Uvalde, Tex., in 1928, and were concluded in 1932. Uvalde County, in the Lower Sonoran of the Lower Austral faunal zone, has an average altitude of 937 feet, an average annual rainfall of 23.71 inches, and an annual mean temperature of 69.7° F.

In southwestern Texas the blowflies, especially the screw-worm fly (*Cochliomyia macellaria* Fab.), are of major importance because of their abundance and their depredations on livestock. In the past the loss of cattle, goats, and sheep caused by blowflies, and particularly the attacks of flies on young calves, kids, and lambs, have at times practically prohibited the breeding of livestock. In recent years conditions have improved. The adoption of progressive and modern

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range methods by ranchmen has lowered the losses considerably. Among these practices may be listed the eradication of cattle ticks, the bite of which was an invitation to fly attack, improved methods of moving and handling cattle, fly trapping, and the prevention of maggot breeding by the burning or burial of animal carcasses. Although bodies of goats, cattle, and other large animals may be destroyed in this manner, numerous smaller carcasses necessarily escape the attention of the ranchman. Many of these small ones are devoured by buzzards and other scavengers, but some of them and portions of others remain as breeding places for flies.

Climatological factors, chemical and bacteriological conditions within the carrion, predators, and competition between the various species of insect larvae combine, during the natural destruction of a carcass, to limit the number and specific nature of blowfly larvae which will mature. Regardless, however, of the united effect of all these natural factors, many maggots complete their development. The importance of a blowfly parasite is measured by the extent of its infestation of host larvae which would otherwise reach maturity in a particular piece of carrion.

A number of parasites attack these maggots, and in addition numerous predators destroy matured fly larvae. Studies are being made of these insects to determine their economic value, both as individual species and collectively as a group, under different climatic and ecological conditions. It is hoped that among these parasites and predators certain species may be found which, if encouraged by artificial means, will form a complex of parasites and predators that will act effectively in blowfly control.

SYSTEMATIC POSITION

Brachymeria fonscolombei is a species of the subfamily Chalcidinae, family Chalcididae, superfamily Chalcidoidea, and order Hymenoptera. Although it was known previously under other names, Dufour (*8*) [1] described the species in 1841, naming it after Boyer de Fonscolombe, and calling attention to the fact that it should be placed in the genus Brachymeria erected by Westwood (*14*) in 1832. However, it continued to be known under the generic name Chalcis until 1923, when the generic name Brachymeria was definitely recognized by Gahan and Fagan (*4*).

DISTRIBUTION

Brachymeria fonscolombei is generally distributed over central Europe, extending into Russia and Asia. Specimens collected in Batavia, Java, are in the United States National Museum. In North America it has been found throughout the southern part of the United States, from Florida to California and as far north as Illinois. Specimens are known from Mexico and Haiti.

The records of distribution in Europe have been taken from literature. The distribution in the United States and Mexico is based on specimens collected or examined by the author.

Europe.—Italy: Tuscany (*11*), Liguria (*7*), Sicily (*13*); France: Var (*9*), southern France (*3*); Spain: Province of Madrid (*8*), Province of Ciudad Real (*8*); Austria:

[1] Italic numbers in parentheses refer to Literature Cited, p. 21.

Lower Austria (*12*), Tyrol (*12*), Küstenland (*12*); Herzegovina: Stolac (*12*); Germany: Brandenburg (*12*); Sweden: southern part (*2*); Russia: Transcaucasia (*12*), Waluiki (*12*).

Asia.—Nord-Mongolei (*12*); Java: Batavia.

North America.—Mexico: Tampico, Tamaulipas; West Indies: Port au Prince, Haiti; United States: Arizona, Arkansas, California, Florida, Illinois, Kansas, Louisiana, Oklahoma, Maryland, Mississippi, New Mexico, Texas.

DESCRIPTION

The original description of *Brachymeria fonscolombei* by Dufour (*3, p. 16*) was published in 1841. Additional descriptions have been made by Mercet (*8*), Ruschka (*12*), Masi (*6, 7*), and others. Parker (*10*), in 1924, gave descriptions and figures of the egg and larval stages. These various descriptions state that the length of adults of *B. fonscolombei* ranges from 3.5 to 6 mm. Dufour (*3, p. 17*) says that it varies greatly in size like *Chalcis minuta*, and this difference in size is independent of sex. The adult female is shown in Figure 1.

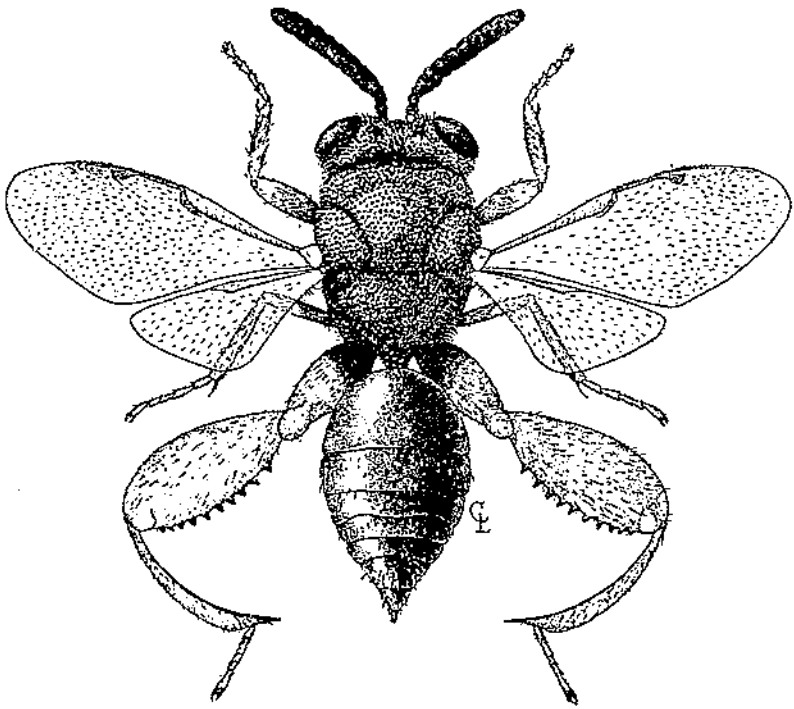

FIGURE 1.—Adult female of *Brachymeria fonscolombei*. × 12. (Drawing by C. Lewis.)

SIZE OF ADULTS

Specimens in the collection at Uvalde, Tex., indicate variations of from 3 to 6 mm in length. Sex of the individuals is partly the cause of this variation, but the differences are mainly due to the species of the host and the size of the host larva at time of pupation. The larger species of flies, such as *Sarcophaga plinthopyga* Wied., when the larvae receive plenty of food and are fully developed, produce *B. fonscolombei* 6 mm long. On the other hand, *Lucilia sericata* Meig. and

Cochliomyia macellaria Fab. produce the same species of parasites 4 mm long, and if the host larvae are undernourished, the parasites are only 3 mm in length. The following measurements are averages of specimens bred from pure strains of flies.

Host:	*Length of parasite adult (millimeters)*
Sarcophaga plinthopyga Wied	4 to 6
Phormia regina Meig	3 to 6
Lucilia unicolor Towns	4
Calliphora coloradensis Hough	4
Synthesiomyia nudiseta V.d.W	3.5 to 4
Lucilia sericata Meig	3 to 4
Cochliomyia macellaria Fab	3.5

Conclusive proof that variations in size occur between the sexes was demonstrated by measuring the lengths of the individuals of the progenies of four female *B. fonscolombei*. In each instance the host was *S. plinthopyga*. In a total of 146 progeny from the four female *B. fonscolombei*, 71 males ranged in length from 4 to 5 mm, averaging 4.7 mm, whereas 75 females ranged between 5.5 and 6 mm, averaging 5.9 mm.

PROPORTION OF THE SEXES

Tests, in which jars, each containing 4 ounces of meat, were exposed and the flies and parasites reared therefrom, were conducted to determine the proportion of sexes in *B. fonscolombei*. Necessarily, the entire emergence of parasites from each test was considered, as the males emerge slightly sooner than the females. Great variation in the proportion of males and females was indicated by the results of the individual tests, but the averages were more consistent. In one test 70 percent were males and 30 percent were females, while in another 22 percent were males and 78 percent were females. The averages for 1930 and 1931 were 45.15 percent males and 54.85 percent females. These latter figures are comparable with those secured from the tests of 1932, which gave 42.41 percent males and 57.59 percent females. An average of all these, based on the emergence of 3,543 *B. fonscolombei*, shows that 43.04 percent were males and 56.96 percent were females. These results indicate a moderate preponderance of females over males.

REPRODUCTION

MATING

Under favorable conditions of warm, bright weather the mating preliminaries of *B. fonscolombei*, in cages, commence almost immediately after the emergence of the parasites. These preliminaries for adults that have emerged during the night or early morning hours are usually well under way by 9 a.m.

The males are attracted to the females and continually follow them about. When two or more couples are together, they change partners frequently, two males often contesting for a female. After about half an hour of preliminary measures the insects mate, the act lasting about 30 seconds. No female has been observed to permit a male to mate with her more than once, although a male will attempt a second mating. Apparently only a single fertilization is required by a female.

OVIPOSITION

Numerous tests have been conducted to determine the length of the preoviposition period. Unmated males and females of known ages, each of which had emerged in a separate glass vial, were used. In each test oviposition was secured within 24 hours after the emergence of the parasite. The shortest preoviposition period was 3 hours, but as males only were secured from eggs deposited during this period, it might be concluded that they were produced by a female that had not been fertilized. However, female offspring resulted from eggs deposited by this insect when it was between 6 and 8 hours old. In one test female offspring were secured from eggs laid before the end of a 7½-hour preoviposition period and in another test before the end of a 6-hour period. It is shown, therefore, that male offspring can be produced from eggs deposited 3 hours after emergence of the parent parasite, and both male and female offspring from eggs laid less than 6 hours after the emergence of the parents. The shortest recorded period between mating of adults and deposition of eggs that produced females was 5 hours. However, from observations it appears that the period between mating and oviposition may be somewhat less than this.

The parasites manifest no preference for any particular portion of the larva for egg laying. There is no indication that they choose the posterior spiracles or stigmal plate, although they have been seen to oviposit there.

Frequently the juices from meat in which larvae have fed will induce *B. fonscolombei* to oviposit. When an individual larva has been offered to a parasite and oviposition is delayed, if the larva is dipped in the juice surrounding the meat and returned to the parasite, oviposition often occurs immediately. Moreover, on numerous occasions oviposition has been brought about by placing a drop of meat juice on the inside of a glass vial and introducing a female *B. fonscolombei*. A parasite has been seen to deposit therein as many as five eggs, in much the same manner as when parasitizing a larva.

As a rule, preliminary to oviposition, the parasite makes a thorough examination of the larva by use of the antennae. During this investigation the female constantly touches the larva with its antennae, then, as though dissatisfied, moves away, perhaps to return again immediately. Females sometimes compete for a larva, the larger or stronger repulsing the other by use of the hind legs.

The adult of *B. fonscolombei* may attack the larva in one of two ways. It may approach the host and, after touching it several times with the antennae, turn, and, bracing the body with the legs, thrust in the ovipositor. The parasite, during this process, appears clumsy, as if unsure of the distance and direction of the host. Often several thrusts will be made with the ovipositor before the host is encountered. The second mode of attack is more efficient. The parasite grasps the larva with the hind legs. While in this position, it has no difficulty in inserting and driving in the ovipositor, and the larva has little chance to escape.

The time required for oviposition is 5 to 15 seconds. Deposition of the egg by the parasite has been observed under a binocular while the fly larva was held between two glass slides. Transmitted light

made it possible to see into and through the maggot. A portion of the body exposed at the edge of the slides permitted attack by the parasite. Oviposition was observed as a simple process in which the ovipositor was thrust through the body wall into the body cavity. The issuing of the egg from the ovipositor took place in an interesting way. First appeared a portion of the chorion, which so quickly filled with the egg contents that it momentarily took the form of a globe; the remainder of the chorion followed immediately and the egg assumed its cylindrical shape. This process required less than a second. The egg floated at once in the body cavity, propelled back and forth by muscular actions of the larva's body. Only one egg was seen to be deposited at a single thrust of the ovipositor.

Immediately upon being attacked, the larva begins thrashing around in an attempt to dislodge its attacker. The parasite, if firmly braced, may be able to hold its position until the ovipositor is withdrawn. If the parasite is on the side of a jar or piece of meat, in a position above the larva, it may even lift the larva into the air, swinging it around for a second. More frequently, however, and especially when the parasite mounts the larva, the pair are thrown into a struggle, each trying to break away.

Following oviposition, the parasite may withdraw and perhaps spend a moment in cleaning the antennae and head, or it may resume oviposition immediately. The larva, on the other hand, continues to thrash about as if suffering from the attack. Sometimes the larva is attacked two or more times in succession.

Eggs have been observed from oviposition until hatching. At 20 hours segmentation is evident, by 24 hours the embryo is twisting about within the egg, and on the third day hatching occurs.

NUMBER OF PARASITES DEVELOPING FROM A SINGLE HOST LARVA

A common habit of *B. fonscolombei* is to deposit more than one egg in a single host larva. A single parasite has been seen to attack a larva as many as 12 times. Frequently when fly larvae are dissected, from 3 to 5 parasite eggs are found in a single larva. In the course of these studies thousands of parasitized blowfly pupae have been isolated in individual glass vials and the parasites allowed to emerge. In no instance has more than one *B. fonscolombei* issued from a single fly pupa. Numerous tests have been conducted in which parasitized fly larvae have been placed under a binocular, illuminated, and the number of parasite eggs counted. Specimens with 2 or 3 parasite eggs were isolated and upon pupation were placed in individual glass vials. Only one parasite emerged from each pupa. In dissecting fly larvae, twin parasite larvae are often found to have developed to the second stage. Apparently after the second stage only one parasite continues to develop.

NUMBER OF EGGS PRODUCED BY A SINGLE FEMALE

The number of eggs which a female *B. fonscolombei* can lay has not been definitely ascertained. From a single female 80 offspring, 26 males and 54 females, were obtained. This represents the largest number of individuals produced by a single parasite under observation. On April 29, 1930, two females were dissected. The first, a medium-sized gravid female, 3 days old, contained 87 perfectly formed eggs

and many more so small that they could not be counted. The second was smaller and contained 85 large eggs. On June 24, 1930, two large, 3-day-old gravid females were examined. In one, 164 clearly formed eggs were found, and 177 in the other. There were numerous smaller immature eggs.

PARTHENOGENESIS

An unfertilized *B. fonscolombei* female will produce fertile eggs, but male offspring only will result. A series of 10 unmated females produced a total of 204 male and no female progeny, and the average developmental period for this series was 19.5 days. In each of these tests the parent parasite emerged from a pupa that had been kept in an individual glass vial, so that any possibility of contact with a male was eliminated. A test was made to determine the fertility of the males produced by virgin females. A male was selected from the progeny of an unmated female and mated with a virgin female that had emerged in an individual glass vial. This pair produced 10 male and 20 female offspring. The appearance of females in this generation is ample proof of the fertility of males produced by virgin females.

DEVELOPMENTAL PERIOD OF IMMATURE STAGES

METHODS

The method used in determining the period between the parasitization of the fly larvae and the emergence of *B. fonscolombei* consisted in exposing fly larvae to parasites under outside conditions and rearing under careful observation the parasites produced therefrom.

FIGURE 2.—Jars used as containers of meat baits in breeding immature stages of *Brachymeria fonscolombei*. Jar on left shows large-mesh cover used during exposure; jar on right has cover of brass strainer cloth used to close jars after exposure.

In all the tests pint Mason jars were used. Each jar contained 1½ inches of slightly moist sand on which was placed a 4-ounce piece of fresh rabbit meat. Each jar was marked with a gummed label showing all data concerning the exposure. Figure 2 shows the breeding jars, and Figure 3 shows the method of exposing the jars in the field.

Ordinarily 6 jars were used in each test, though in some instances the number ranged from 2 to 10. The jars were all exposed under similar conditions, protected only from the sun. In some cases the meat was infested with larvae within the laboratory before exposure and therefore the day of exposure was known to be the exact date parasitization occurred. When meat was exposed without being infested and remained exposed several days, all conditions were carefully checked, and then the day of probable greatest parasitization was chosen as the date from which to figure the beginning of the developmental period. In selecting this date, temperature and weather conditions were studied and observations made to record the appearance of the parent parasites in the jars and their period of greatest activity.

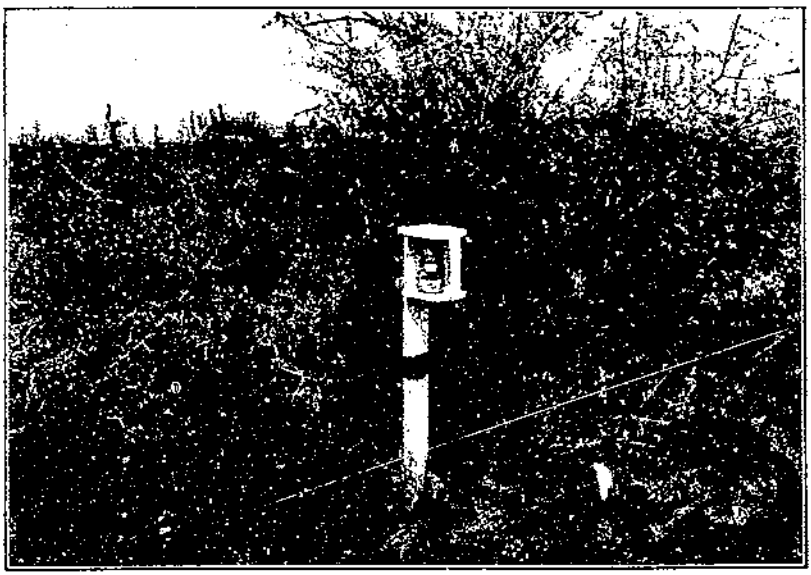

FIGURE 3.—Jar containing meat bait exposed for infestation by blowflies and their parasites. The wooden shelter is protection against rain and animals.

There was no attempt to regulate the species of host flies in these tests. However, species of Sarcophaga predominated. The flies were allowed to infest the meat in a natural way. The relative proportion of species emerging in the jars was roughly as follows:

Species:	*Percent*
Sarcophaga spp	75
Lucilia spp	10
Phormia regina Meig	5
Synthesiomyia nudiseta V.d.W	3
Cochliomyia macellaria Fab	2
Others	5

At the conclusion of the tests the jars were capped with tops of 60-mesh brass strainer cloth and placed on shelves in an insectary where they were under daily observation. Conditions in this insectary approached, as nearly as possible, natural conditions. Shade was the

only protection given the jars, the screened walls permitting outdoor temperatures to prevail. Each insect was determined and recorded the day of its emergence.

LENGTH OF DEVELOPMENTAL PERIOD

Emergence records for each test are listed in table 1. These tests were carried out during 1928, 1929, and 1930, and include records of parasites bred from exposures during the months from March to November, inclusive. Each record presents the number of parasites that emerged, the range in the developmental period, and the average developmental period for the group.

TABLE 1.—*Summary of tests showing developmental period of Brachymeria fonscolombei in blowfly larvae, Uvalde, Tex., 1928, 1929, and 1930*

Date fly larvae were parasitized	Summer broods						Overwintering broods					
	Range of developmental period	Average length of developmental period	Total parasites in summer brood	Temperatures			Range of developmental period	Average length of developmental period	Total parasites in overwintering brood	Temperatures		
				Maximum	Minimum	Average of daily means				Maximum	Minimum	Average of daily means
	Days	*Days*	*Number*	*°F.*	*°F.*	*°F.*	*Days*	*Days*	*Number*	*°F.*	*°F.*	*°F.*
Mar. 25, 1929	26–33	27	456	97	53	75						
Mar. 27, 1930	32–37	35	12	95	30	70						
Apr. 10, 1930	27–36	32	12	94	47	75						
May 6, 1930	25–27	26	5	94	47	78						
May 21, 1930	23–36	26	137	97	60	78						
June 5, 1930	20–27	22	181	100	64	81						
June 27, 1928	17–26	21	870	104	73	88						
July 11, 1928	20–29	24	265	102	70	86						
Aug. 1, 1930	18–24	21	22	104	70	86						
Aug. 2, 1930	19–26	21	81	104	65	86						
Aug. 3, 1930	10–22	10	43	104	70	86						
Sept. 4, 1930	20–26	23	30	102	59	82						
Oct. 5, 1928	42–69	51	9	94	28	63	171–191	178	37	100	20	60
Oct. 15, 1928	42–83	49	44	89	20	57	163–181	173	376	100	20	59
Oct. 20, 1928	78–93	82	8	87	29	56	156–176	167	318	100	20	59
Oct. 22, 1928							143–174	166	302	100	20	59
Oct. 27, 1928							156–169	164	182	100	20	58
Oct. 30, 1928							153–165	161	62	100	20	58
Nov. 3, 1928							149–155	150	20	100	20	57
Nov. 6, 1928							153–156	155	11	100	20	58
Total	16–93		2,175				143–191		1,308			

Many host larvae and pupae from these tests were dissected in the laboratory, and it was found that in warm weather the period from the hatching of the parasite larva until it reached maturity was from 8 to 12 days. The host larva pupates during this period, and the parasite larva continues its feeding until the host pupa is destroyed, after which it in turn pupates and remains in this stage for a period of about 10 to 12 days.

Temperatures (Fahrenheit) during these tests were recorded from the date the larvae were parasitized until the end of the emergence period of the parasites. For each test the extreme maximum and minimum and the average of the daily means are given.

In the course of these tests 3,483 *B. fonscolombei* were reared. A satisfactory test was started as early as March 25. The average developmental period in this case was 27 days. Thereafter, generally

speaking, with the increase of daily mean temperatures this period shortened. During August an average period of 19 days, a minimum mean for the tests, was recorded. After August the period of development rapidly lengthened. Of the brood starting from October 1 to 20, only part emerged, and the remainder overwintered within the host. Of those starting late in October and in November, all overwintered in immature forms.

The shortest period of development for immature stages encountered was from a test initiated August 3, 1930. From larvae parasitized on this date, two *B. fonscolombei* emerged on August 19, after a period of 16 days. The average developmental period for this entire group was 19 days, while the average for all tests conducted during August was 20 days.

The longest period noted for the development of an individual that did not overwinter in immature form was 93 days. This was a parasite which emerged January 21, 1929, from an egg deposited October 20, 1928. The greatest period for an overwintering individual was 191 days, from October 5, 1928, to April 14, 1929.

RELATION OF TEMPERATURE TO DEVELOPMENT

The effect of variations in temperature on the development of *B. fonscolombei* is plainly evident. On the basis of the data summarized in table 1, the developmental periods may be arranged in groups, each with an average daily mean temperature range of 5°. The average lengths of the developmental periods of the groups are as follows:

Range (° F.):	*Period (days)*
86 to 90	21.5.
81 to 85	22.
76 to 80	26.
71 to 75	27.
66 to 70	35.
61 to 65	51 (some overwinter).
56 to 60	55 (some overwinter).
Below 55	No fall emergence; all overwinter.

The minimum temperature for ordinary activity and development was near 65° F. In the fall, in periods where the mean temperature fell below 65°, a portion of the brood overwintered. Oviposition was secured in 1929 throughout October and early November. At this time daily maxima of 65° or higher were suitable for oviposition by *B. fonscolombei*, but the mean temperature for the period, being below 65°, precluded complete development of the parasites.

From the last emergence of a parasite of a summer brood of 1928 until the first emergence of one from an overwintering brood in 1929, the average daily mean temperature was 54° F., with a maximum of 93° and a minimum of 20°.

In 1930 oviposition was secured as late as November 18. On this date four adult *B. fonscolombei* were active at 3 p.m. The temperature at that time was 80° F., the maximum for the day, the minimum for the previous night being 43°.

NUMBER OF GENERATIONS PER YEAR

In calculating the number of generations of *B. fonscolombei* per year, it is necessary to determine the length of the immature stages during each month throughout the year and derive the number of generations

therefrom. Naturally, the breeding habits of this insect bring about an overlapping of generations which precludes a periodic rise and fall in the population curve. Although the members of the overwintering generation emerge almost simultaneously, several factors unite to induce variations in the following broods. Delays may arise through the difficulties of individuals in locating hosts. These discrepancies may be accentuated in successive generations by variations in the length of the developmental periods of individuals.

Before computing the length of a generation, it was necessary to assume an arbitrary preoviposition period. In fixing this period, certain factors had to be considered. While it has been shown that females, given perfect conditions, can oviposit within a few hours after emergence, it must be remembered that unsuitable conditions will bring about delays. Also, in the field, the males and females may not find each other readily, and subsequent to mating, the females must locate the host larvae. The longer preoviposition periods of spring and fall will tend to increase the average period for the year. From these considerations a preoviposition period of three days was selected.

At Uvalde *B. fonscolombei* ordinarily appears and begins to oviposit about March 20. From late in March to mid November climatic conditions at Uvalde are favorable to the development of *B. fonscolombei*. If host larvae are available throughout this period, eight generations might occur, a portion of the eighth overwintering in immature stages. As previously explained, these generations overlap. Figure 4 indicates the number of generations that might occur per year on the basis of the average developmental period for each month. It should be clearly understood that the number of generations shown in this figure represents the maximum number of generations possible during the season, on the basis of the average developmental periods during the various months, and does not necessarily represent the seasonal cycle in the field.

LONGEVITY

It is evident from numerous observations that neither food nor water is necessary for adults of *B. fonscolombei* previous to oviposition. However, they will partake readily of water and will feed upon bananas or other fruit. It is likely that the adults secure water and perhaps food from the juices present on the meats which they frequent and upon the liquids which often surround fly larvae. Certain foods lengthen the life of *B. fonscolombei*, but water alone seems to have no effect.

Increased temperature decreases the length of life. Adults held in captivity without food or water at temperatures with a mean of from 80° to 90° F. lived from 1 to 6 days, the average being 2.5 days. At a mean temperature of 70° to 79° the longevity was from 1 to 6 days and the average 3.6 days. Below 60° (50° to 59°) the range was from 7 to 23 days and the average 9.4 days. When the insects were given water only at a mean temperature of from 80° to 90° the length of life was from 1 to 5 days and the average 2.8. Banana and water both being given, at a mean of from 80° to 89°, the longevity was from 1 to 6 days and the average 3.8 days; at a mean temperature of from 70° to 79° the range was from 2 to 6 days and the average 4.5 days; at a mean temperature of 60° to 69° it was from 3 to 6 days and the

average 5.6 days. Provided with a diet of honey only, at a mean temperature of from 80° to 90°, the insects lived from 1 to 23 days, the average life being 11 days.

These longevity tests were made, so far as temperature and humidity were concerned, under natural conditions. It was necessary, however, to confine the Brachymeria in cages that permitted daily observations. Two types of cages were used; one consisted of pint Mason jars with screen tops, the other of 10-inch screen cylinders, 6 inches in diameter. The results obtained with the two types of cages were about the same.

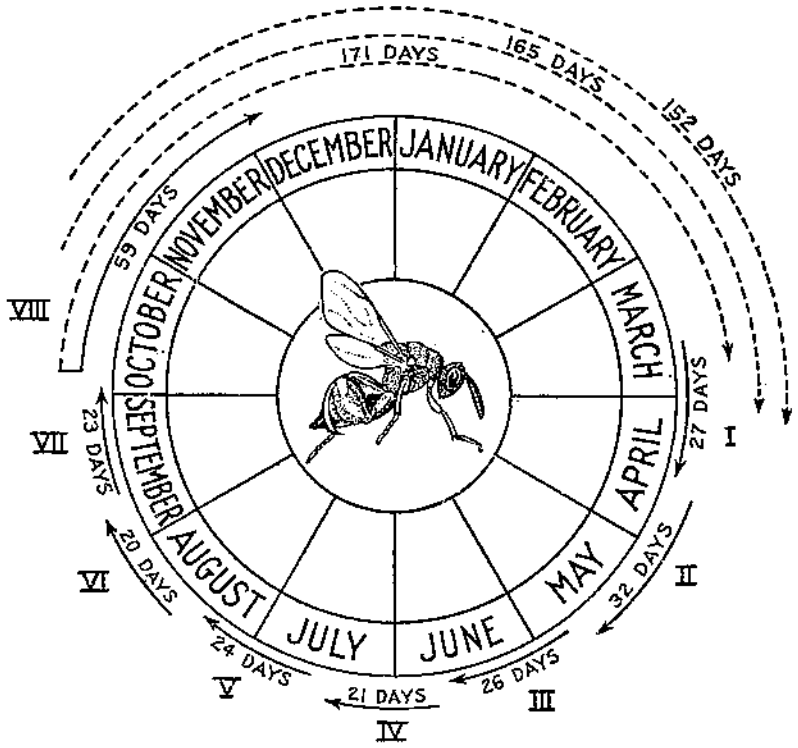

FIGURE 4.—A calendar year for *Brachymeria fonscolombei* at Uvalde, Tex., showing maximum number of generations per year and average length of developmental period of parasite. Summer broods are represented by solid lines, overwintering broods by broken lines.

Water was given in a small glass dish containing a sponge. Banana, when used, was sliced, a fresh slice being furnished each day. The honey was not diluted; and it had no opportunity to ferment, as fresh honey, on a sponge, was supplied daily.

An extensive study was not made of the difference in longevity of the sexes. Incomplete data and observations indicate that the male outlives the female by a day.

HIBERNATION

Brachymeria fonscolombei passes the winter in the last larval or prepupal stage within the host pupa. The relation of temperature to overwintering is discussed under Developmental Period of Immature

Stages, where it is shown that in October and November, when the average mean daily temperature goes below 65° F., a portion of the last summer brood of parasites overwinters in the immature form. *B. fonscolombei* has been carried successfully through the winter in pure strains of *Sarcophaga plinthopyga*, *Cochliomyia macellaria*, and numerous mixtures of Sarcophaga and Lucilia. Examination of the blowfly pupae from October to March during 1928 to 1932 revealed that the parasites develop to the last larval or prepupal stage and remain thus until late February or early March, when they begin transforming to the pupal stage. Some of the parasites are ready to emerge on warm days in the middle of March or, with an early spring, they may emerge sooner. In 1928 *B. fonscolombei* emerged and oviposition was secured on March 18. In 1932, following a warm winter, a specimen emerged February 26. Oviposition usually ceases in early or mid November. A few adults may emerge during December, and occasional specimens have emerged in January.

Jars of blowfly larvae and pupae were carried through the winter of 1928–29, from which emerged 1,308 *B. fonscolombei*. These parasites hibernated for an average period of 168 days, with an extreme for three individuals of 191 days.

Observations and tests show that *Brachymeria fonscolombei* larvae do not overwinter in host larvae but in host pupae. Large numbers of blowfly larvae were parasitized in October, 1928. In November the blowfly pupae were separated from the larvae which had not pupated. *B. fonscolombei* emerged the following spring from the pupae only. This would tend to corroborate the results of Holdaway (*5*), who found parasitization by *Alysia manducator* Panzer to be a stimulus to pupation in Lucilia.

There is no evidence that *B. fonscolombei* overwinters in adult form. Adults have never been observed or collected during midwinter. Numerous experiments have been conducted in which adults were given the opportunity to hibernate in soil, dried meat, wood shavings, and burlap. In every instance the adults sought to escape. They lived only the normal time, about 9.5 days. The greatest longevity recorded was that of one individual which lived 23 days.

HOSTS

While the hosts of *B. fonscolombei* were being studied, precautions were taken that no contaminations of the tests might occur. For the work with *Phormia regina* or *Cochliomyia macellaria*, these being the only representatives of their respective genera occurring at Uvalde, larvae were secured from a pure strain of each species. In each of the other tests the progeny of a single female fly was used. For breeding media, meat was removed from rabbit carcasses immediately after the rabbits were killed. In each test 2 ounces of this meat was placed in a pint Mason jar containing 1½ inches of sand and capped with 60-mesh screen gauze. Ordinarily the female fly was placed within the jar and allowed to oviposit on the meat, although occasionally oviposition was secured in another jar and the eggs transferred. These preliminaries were conducted as quickly as possible under constant observation and within a screened insectary. As soon as the fly was introduced, the jar was placed in a glass-top breeding cage in a fly-proof insectary. This procedure prevented any contamina-

tion by Sarcophaga or other flies. After the fly eggs had hatched, parasites were placed within the jar. Later both the parent fly and parasites were pinned and saved for further study. The parasitized larvae, after feeding had been completed, pupated in the sand; and, upon emergence, the second generation of flies and parasities were recorded and saved.

LIST OF HOST SPECIES

Brachymeria fonscolombei has been bred from numerous species of Diptera of the familes Calliphoridae, Sarcophagidae, and Muscidae. The following list includes all known authentic host records.

Family Calliphoridae: *Calliphora coloradensis* Hough, *Lucilia sericata* Meig., *L. unicolor* Town., *Phormia regina* Meig., and *Cochliomyia macellaria* Fab.

Family Sarcophagidae: *Sarcophaga plinthopyga* Wied., *S. impar* Ald., *S. haemorrhoidalis* Fall., and *S. carnaria* L.

Family Muscidae: *Synthesiomyia nudiseta* V.d.W.

HOST CASE RECORDS

Calliphora coloradensis Hough.—Uvalde, Tex. March 19, 1930, progeny of single fly (eggs deposited March 17) exposed to parasites. Oviposition continued until March 23. March 15–16, 10 *C. coloradensis* (identified by Laake) emerged; average developmental period 29 days. April 26–May 6, 7 *B. fonscolombei* (identified by Gahan) emerged; average developmental period 37 days.

Lucilia sericata Meig.—Uvalde, Tex. May 17, 1930, progeny of single fly (eggs deposited May 16) exposed to parasites. June 1, about 100 *L. sericata* (identified by Laake) emerged; average developmental period 16 days. June 18, one *B. fonscolombei* emerged; developmental period 30 days.

Uvalde, Tex. September 3, 1931, progeny of single fly (eggs deposited September 1) exposed to parasites. September 15–16, 12 *L. sericata* emerged; average developmental period 18 days. September 21–25, 16 *B. fonscolombei* emerged; average developmental period 20 days.

Lucilia unicolor Town.—Uvalde, Tex. September 3, 1930, progeny of single fly (eggs deposited September 1) exposed to parasites. Parasitization continued until about September 5. September 15–19, 50 *L. unicolor* (identified by Laake) emerged; average developmental period 15 days. September 29, one *B. fonscolombei* emerged; developmental period 25 days.

Phormia regina Meig.—Uvalde, Tex. June 24, 1930, larvae from pure strain of *P. regina* (eggs deposited June 22 from specimens received from North) exposed to parasites. July 6, 107 *P. regina* (identified by Laake) emerged; average developmental period 14 days. July 11–15, 111 *B. fonscolombei* emerged; average developmental period 18 days.

Cochliomyia macellaria Fab.—Uvalde, Tex. August 18, 1921, larvae from egg mass of *C. macellaria* (identified by Parman) deposited August 16 exposed to parasites. September 5–6, five *B. fonscolombei* (identified by Gahan) emerged; average developmental period 18 days. Record by Parman.

Uvalde, Tex. October 6, 1928, lot of about 100 larvae taken from a strain of pure *C. macellaria* were exposed to parasites. Some of the parasites overwintered in the host pupae. November 26, 1928, six *B. fonscolombei* emerged; average developmental period 51 days. March 25–April 1, 1929, five *B. fonscolombei* (identified by Gahan) emerged; average developmental period 174 days.

Sarcophaga plinthopyga Wied.—Uvalde, Tex. July 10, 1929, larvae from single female fly larviposited and placed with parasites. Parasitization continued; July 11 assumed as average date of parasitization. July 30, 20 *S. plinthopyga* (identified by Hall) emerged; average developmental period 20 days. July 31–August 2, 27 *B. fonscolombei* (identified by Gahan) emerged; average developmental period 21 days.

Uvalde, Tex. May 25, 1930, larvae (larviposited May 24) from a single fly exposed to parasites. June 18–20, three *S. plinthopyga* (identified by Hall) emerged; average developmental period 26 days. June 20–24, 65 *B. fonscolombei* emerged; average developmental period 27 days.

Sarcophaga impar Ald.—Dallas, Tex. August 24, 1928, larvae taken from dead bird, placed on beef, and exposed to parasites. September 13–14, 11 *S. impar* (identified by Laake) emerged. September 13–16, 34 *B. fonscolombei* emerged; average developmental period 22 days.

Sarcophaga haemorrhoidalis Fall.—Reference: Dalla Torre (*1, p. 258*).

Sarcophaga carnaria L.—Reference: Stefani (*13, p. 11–12*).

Sarcophaga sp. Reference: Parker (*9, p. 239*). Parker said: "We have reared *C. fonscolombei* from various species of the genus Sarcophaga living in a larval state in decomposing meat * * *."

Synthesiomyia nudiseta V.d.W.—Uvalde, Tex. August 4, 1930, progeny of single fly (eggs deposited August 2) exposed to parasites. August 16–17, 52 *S. nudiseta* (identified by Aldrich) emerged; average developmental period 15 days. August 22–25, 32 *B. fonscolombei* emerged; average developmental period 19 days.

Although efforts were made to breed *B. fonscolombei* from *Calliphora erythrocephala* Meig. and *Cynomyia cadaverina* Desv., they were unsuccessful. There is little doubt, however, that the parasite will breed in these two species. Attempts to rear the parasite from *Musca domestica* L. and *Ophyra aenescens* Wied. also failed. It is not impossible that *B. fonscolombei* will breed in these two flies.

PREFERENCE FOR HOST

Demonstration has been made, both in breeding tests in the laboratory and in rearing parasites from field collections, that *B. fonscolombei* can be bred in greatest numbers when the host is a species of the genus Sarcophaga. Thirty host tests were made with various species of flies. *B. fonscolombei* was bred in only three tests from Lucilia larvae, whereas eight tests were failures, while during several years of work with the parasite it was bred in only two instances from *Cochliomyia macellaria*.

An experiment was conducted during the summer of 1930 to determine whether *Brachymeria fonscolombei* exhibited any host preference under natural conditions. For this experiment four shelters such as that shown in figure 5, A, were constructed. Each consisted of a wood frame with sides of 8-mesh hardware cloth, and a solid removable lid. The purpose of this shelter, which was made as open as possible, was to protect the bait from the sun and to keep out animals. In each shelter a bait, consisting of two skinned rabbit carcasses, weighing 10 pounds, was exposed. This meat was placed in a tin pan 4 inches deep and set inside a tub which contained 5 inches of sand. The sand furnished a pupating place for larvae that finished their feeding before the end of the exposure period. The tub had a 6-inch band of cup grease smeared around the upper inside rim to prevent larval migrations. The four tests were located about one half mile apart in a pasture and were not disturbed from the time they were started until they were ready to be rebaited. Rabbit carcasses exposed in this manner permitted flies and parasites to work in a natural way. At the time of collection the larvae were separated according to species, and a representative sample taken of each. Figure 5, B, shows various gaged sifters used to separate pupae and larvae from the sand.

Table 2 shows the results from 12 tests made from June, 1930, to August, 1931. In no instance was a parasite bred from *Cochliomyia macellaria* or from *Lucilia* sp. Of the total emergence from Sarcophaga, 21.4 percent was *B. fonscolombei*. Of the original number of

Sarcophaga larvae, 16.3 percent produced *B. fonscolombei*. The death rate of Sarcophaga from other causes was 23.5 percent, whereas the death rate of *C. macellaria* was only 7.2 percent.

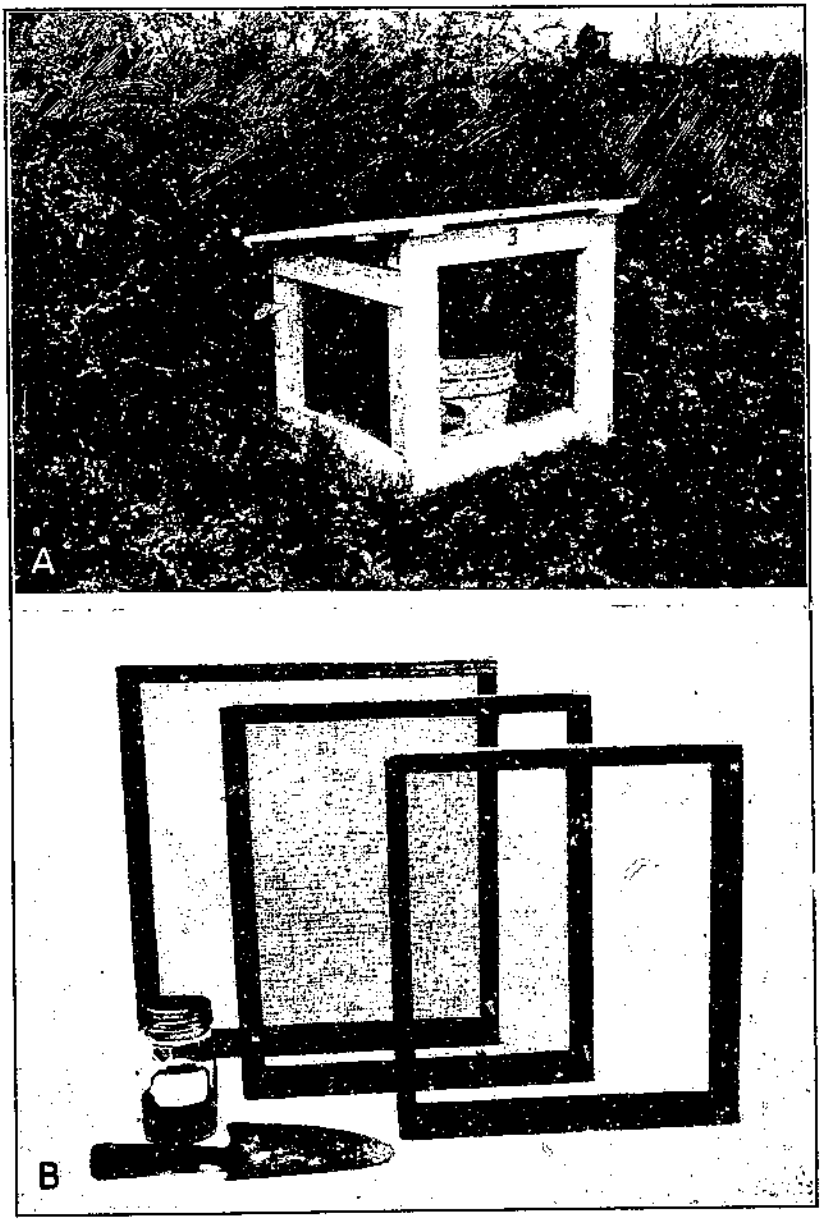

FIGURE 5.—A, Tub containing rabbit carcasses exposed to blowflies and their parasites. The shelter furnished protection against sun, rain, and animals. B, Sifters of 14-mesh screen wire and 6- and 10-mesh hardware cloth used in separating blowfly larvae and pupae from sand.

TABLE 2.—*Parasites bred from larvae reared from 12 rabbit carcasses exposed under natural conditions, showing host preference of Brachymeria fonscolombei. Uvalde, Tex., June 12, 1930, to Aug. 14, 1931*

Host	Fly larvae reared	Flies emerged	Parasites		Proportion of fly larvae parasitized[1]	Proportion of fly larvae and pupae that died[2]
			Emerged	Proportion of total emergence		
	Number	*Number*	*Number*	*Percent*	*Percent*	*Percent*
Cochliomyia macellaria	1,550	1,439	0			7.2
Sarcophaga sp.	1,550	932	253	21.4	16.3	23.5
Lucilia sp.	700	201	0			71.3
Total or average	3,800	2,572	253	9.0	6.7	25.7

[1] Not including unknown number of parasitized larvae that died.
[2] Not including those that yielded parasites.

THE SCREW-WORM FLY AS A HOST

In two tests only were *Brachymeria fonscolombei* bred from larvae of *Cochliomyia macellaria*, although dozens of exposures were made. In some instances larvae and parasites were confined together in jars, and in other tests large numbers of larvae were collected after having developed naturally in carcasses. In the host-preference tests no Brachymeria were secured from 1,550 *C. macellaria* larvae collected from carcasses where parasites were known to be active. However, numerous observations have been made of the parasite attacking screw worms. On most occasions, when confined together, Brachymeria was seen to oviposit in the maggots.

In October 1931 a study was made to determine the fate of parasite eggs placed in screw-worm larvae. Mature maggots of *C. macellaria* were exposed to *B. fonscolombei* for a single day. On the third day following parasitization, unparastized flies began emerging. Examination of the remaining pupae showed living second-stage larvae of *B. fonscolombei*. In some pupae the parasites, still in the second stage, lived until the seventh day. Below are shown daily records from the test.

October 7, 1931. Mature *C. macellaria* larvae exposed to *B. fonscolombei*. Larvae beginning to pupate.

October 8. Parasite eggs found in larvae which had not pupated.

October 9. Ten puparia opened; no parasites found.

October 11. Flies began emerging from unparasitized pupae. Ten puparia opened; one contained a single second-stage parasite larva, another a small second-stage and a first-stage parasite larva. Each of the flies in the puparia had a well-developed head, thorax, abdomen, legs, antennae, and head and body bristles, but they appeared lifeless. The remaining eight puparia contained living flies.

October 12. Thirty adult *C. macellaria* emerged. Five puparia examined; four contained dead flies and small living second-stage parasite larvae.

October 13. Five puparia examined; one had dead fly only; the remainder contained dead flies, two with single and one with triplet second-stage parasite larvae. The parasites, all living but one (a single), were in each case in the thorax of the fly pupa.

October 14. Five puparia opened; all contained dead flies badly disintegrated; one had twin (one dead) and one had triplet second-stage parasite larvae.

October 16. Ten puparia examined; seven had dead flies, and three had dead flies and dead second-stage parasite larvae. The Brachymeria larvae were brownish, collapsed, and appeared to be rapidly disintegrating.

October 18. Ten puparia examined; all contained decomposing or mummified flies except two; these had in addition the collapsed remains of Brachymeria larvae.

October 19. Thirty-four remaining puparia opened; all contained mummified flies or decomposed masses.

These observations demonstrate that under certain conditions *Cochliomyia macellaria* larvae are attacked by *Brachymeria fonscolombei* but that both host and parasite meet death. It is probable that, because the life cycle of *C. macellaria* is several days shorter than that of Sarcophaga, the parasite larva does not have sufficient time to complete development before the death of the host brings about destruction of the parasite. In the host-preference tests *C. macellaria* had a death rate of only 7.2 percent during the pupal stage. Under natural conditions, then, the percentage of infestation in this species must be very small.

BRACHYMERIA FONSCOLOMBEI BREEDING IN CARCASSES

The results of collecting blowfly larvae from carcasses and rearing therefrom the flies and parasites indicate that *B. fonscolombei* is more active around small carcasses. This may be due to the fact that Sarcophaga is mostly present in small carcasses, while *C. macellaria* predominates in the larger ones. It appears, therefore, that *B. fonscolombei* is of greatest economic importance in its relation to the blowflies frequenting small carcasses. These are largely Sarcophaga and Lucilia during the warmer months and Phormia, Calliphora, and Sarcophaga during the remainder of the year.

Table 3 shows the results of a number of collections from carcasses of various sizes.

TABLE 3.—*Insects bred from blowfly larvae collected from carcasses of various sizes, 1928–31*

Collection date	Kind of carcass	Size or weight	Fly larvae collected	Flies emerged			*Brachymeria fonscolombei*	
				Cochliomyia macellaria	Lucilia	Sarcophaga	Emergence	Proportion of total emergence
1928			*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*
Aug. 17	Horse	Large	1,000	501				
Aug. 23	Goat	Medium	1,000	166	5			
1929								
June 7	Rabbit	5 pounds	[1] 300			200	93	32
June 27	Rabbit in bait pan of cone trap.	do	[1] 200		3	113	111	49
Aug. 6	Rabbit	do	[1] 100			79	13	14
Aug. 22	Turtle	1 pound	[2]			229	16	7
Oct. 31	Goat	Medium	[1] 10,000	[3]				
1930								
May 13	Nestling sparrow	15 grams	[2]			1	93	99
June 17	Sparrow	24 grams	[2]		83	3	12	12
Do	do	do	[2]		175		25	13
June 23	5 goats	Medium, 5 together.	[1] 10,000	[3]				
Sept. 5	Goat	Medium	[1] 1,000	[3]				
1931								
July 17	Redbird	50 grams	[2]		28	5	18	35
July 20	Fish head	1 pound	[2]		109	53	173	52
Aug. 23	Cow	Large	400	340				
Sept. 2	do	do	300	268				

[1] Approximate. [2] All. [3] Many.

These results are corroborated by those shown in table 2, in which Brachymeria were secured in 12 tests where two rabbit carcasses (10 pounds) were exposed. Several thousand 4-ounce meat baits have been exposed in pint jars; *B. fonscolombei* worked readily in bait of this size.

ARACHNID AND INSECT ENEMIES OF BRACHYMERIA

Two instances have been recorded of the spider *Phidippus carolinensis* Peckham preying upon *B. fonscolombei* (Uvalde, Tex., July 24, 1930, and Sept. 21, 1931). While numerous parasites may be caught by this and other species of spiders, the total effect on the species is probably negligible.

Several *B. fonscolombei* placed in cages with *Stagmomantis carolina* Johan. were readily captured and eaten, but it is unlikely that many of these parasites fall prey to this mantid in nature.

No secondary parasites of *B. fonscolombei* have been demonstrated, though several common pupal parasites of Diptera may act as such. Tests made that allowed *Mormoniella vitripennis* (Walk.) to parasitize Sarcophaga pupae already containing *B. fonscolombei* failed to give an emergence of either the parasites or the host. These tests, however, were not extensive.

THE ABUNDANCE OF BRACHYMERIA FONSCOLOMBEI AND ITS IMPORTANCE AS A FACTOR IN BLOWFLY CONTROL

From April through October *B. fonscolombei* is abundant and can be observed wherever small baits are exposed. In many instances more than 200 *B. fonscolombei* have emerged from larvae produced in a 4-ounce piece of meat. During the years 1929, 1930, and 1931 (from April through September), 1,880 4-ounce meat baits were exposed. From larvae produced in these baits were reared 22,639 *B. fonscolombei*, 35 percent of the emergence of flies and parasites.

At Menard, Tex., in 1930, an average of 6.5 percent of the emergence from meat baits was *B. fonscolombei*, with a maximum average emergence from one series of exposures of 25 percent. In the same area during 1931 there was an emergence of 12 percent *B. fonscolombei*. At Brownsville, Tex., during 1930, 9 percent of the emergence from meat baits was *B. fonscolombei*.

It should be distinctly understood that the emergence figures of *B. fonscolombei* from 4-ounce meat baits are presented merely as an indication of the activity of this parasite and not as the exact extent of its effect on blowflies. However, it is interesting to observe that the percentage of emergence is about the same as that secured from small carcasses.

Consideration has been given to the possible effect *B. fonscolombei* might have upon such important Diptera as *Sarcophaga kellyi* Ald., which parasitizes grasshoppers. There are no records of *B. fonscolombei* having been reared from dipterous larvae secured from grasshoppers, although there are several records in which *B. coloradensis* Cress. is mentioned. *Brachymeria fonscolombei* is present in Kansas and Oklahoma, and if it greatly affects these Saracophaga, some mention of it would have appeared in published records before now.

At Uvalde about 33 percent of the maggots that mature in small carcasses not containing larvae of *C. macellaria* are infested with

B. fonscolombei. Table 3 shows small-carcass infestations ranging from 7 to 99 percent. When *C. macellaria* is included, the percentage of parasitization of matured maggots is about 9 percent. Therefore, in relation to the flies which infest small carcasses and in so much as they affect the total fly population, this parasite is of considerable importance. Its effect on the screw-worm fly, *C. macellaria,* however, is small, and it offers little promise in the control of this species.

SUMMARY

Brachymeria fonscolombei (Dufour), the larval parasite of blowflies, is well distributed over Europe and North America and has been found in Asia. The female parasite pierces the host larva and deposits the egg therein. The egg hatches on the third day, and the larva moves freely about in the body cavity. In warm weather the larva matures in 8 to 12 days. During this time the host larva pupates. After the parasite has destroyed the contents of the host puparium, it in turn pupates. The pupal stage lasts about 10 to 12 days.

The preoviposition period may be very brief, oviposition under ideal conditions occurring on the first day of adult existence. Although several eggs are often deposited in the host, this is a solitary parasite, and only one larva reaches maturity. A few more females than males are produced, about 57 percent females to 43 percent males. Parthenogenetic reproduction may also occur.

The developmental period from egg to adult requires an average of 21 days at a mean temperature of 86° to 90° F. With decreased temperatures this period increases, until at 65° the average developmental period is 35 days. At lower temperatures a portion of the brood overwinters as last-stage larvae in the host pupae. Eight generations may occur at Uvalde, Tex., a portion of the eighth overwintering.

Without food or water, at 70° to 79° F., adults of *B. fonscolombei* live about 3.6 days. Increased temperatures shorten this period. When bananas and water were furnished, the longevity was increased to 4.5 days. Honey, as a food, extended the period to 11 days.

Brachymeria fonscolombei is most active as a parasite of Sarcophaga. However, it readily parasitizes Synthesiomyia and Phormia and was frequently bred from Lucilia and Calliphora. The parasite was rarely secured from the screw worm, *Cochliomyia macellaria* Fab., and it was demonstrated that when *B. fonscolombei* parasitizes this species both insects ordinarily meet death.

B. fonscolombei is found breeding in fly larvae in carcasses of birds, rabbits, turtles, and other small animals. At Uvalde about one-third of the larvae in small carcasses are parasitized, though in numerous cases a much greater degree of parasitization was secured.

Although *B. fonscolombei* appears to be of little promise in controlling the screw-worm fly, it should, because of its habit of attacking fly larvae in small carcasses which easily escape man's attention, be of value, if used in conjunction with some parasite of *C. macellaria* and with other insect enemies of blowflies, to form a parasite-predator combination for reducing the blowfly population.

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