THE BIOLOGY AND ECOLOGY OF THE CORN SEED BEETLE

(*AGONODERUS PALLIPES* FAB.)

by

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INTRODUCTION

Each summer for several years, reports of injury to planted seed corn by the corn seed beetle A. pallipes Fab. have been received by the Department of Entomology at Kansas State College and by the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine.

The beetle has been known to be injurious to planted corn since 1885. However, it was not considered a pest to seed corn until the past few years. Prior to 1885, the corn seed beetle was thought to be strictly carnivorous. It is now known to be injurious to many kinds of planted seeds as well as to the corn seed.

The beetles are present in such large numbers in the fields that, with optimum conditions for the beetle, the farmer could be subject to heavy losses due to injury to the germ of planted corn by the adults. Since very little was known concerning the biology of the beetle prior to 1937, and because of its great numbers with its potentialities as a pest under certain ecological conditions, investigation of the biology of the corn seed beetle was started at Kansas State College in the spring of 1937.

REVIEW OF LITERATURE

Taxonomic Literature

The identity of the beetle since Fabricius has been mistaken many times. Another species, _A. comma_ Fab., as Casey (1914) states, has been frequently confused with it. _A. pallipes_ Fab. belongs to the order Coleoptera; family, Carabidae; subfamily, Harpalinae; tribe, Acupalpini, and to the genus Agonoderus. _A. pallipes_ Fab., the corn seed beetle, was first described by Fabricius as _Carabus pallipes_ Fab., and the description published in the Entomologia Systemia I, in 1795, Leng (1920).

Since Fabricius, the beetle has been known at various times as _A. pallipes_ Fab., Fabricius (1795); _A. comma_ Fab., Riley (1880); _A. lecontei_ Chaud., Leconte (1868); _A. rugicollis_ Lec., Riley (1880); _A. pallipes_ Lec.

Agonoderus pallipes Fab., according to the literature, has been placed in two different tribes, the first, the tribe Harpalini by Leconte and Horn (1883) and the second Acupalpini by Casey, in which tribe it is known today.

The tribe Acupalpini appears to be the more appropriate classification because in such an arrangement it breaks up the complex grouping in the tribe Harpalini, raises the tribe to the subfamily Harpalinae, which, in turn, is separated into tribes. This arrangement also permits the taxonomist to work with the various species with greater ease. Frequently, the earlier writers placed so many genera into one tribe that the tribe become unwieldy. The beetle was placed in the tribe Acupalpini under the subfamily Harpalinae by Casey (1914).

The members of this tribe are characterized by the following characters: the second joint of the labial palpus is bisetose in front and has one posterior seta on the same segment. Casey (1914) describes the tribe Acupalpini as:

> Second joint of labial palpi bisetose in front; frontal impressions isolated or continued obliquely backward in a more or less fine canaliculation to the middle of the eyes; tarsi variously modified sexually; body always small to very small in size.

The genera are numerous when compared with the known species of the other tribes, indicating an unusual amount of structural diversification. Casey (1914) says of raising the tribe Harpalini to the subfamily Harpalinae:

> It is preferable to regard the major groups of Carabidae which were termed tribes by Leconte and Horn as subfamilies, as is done in Europe-- The classification of Carabidae now accepted has resulted from a very gradual process of evolution--The arbitrary arrangement of the earlier authors was measurably improved by the work of Leconte in 1853 and it is easy to trace some subsequent generalizations from this early work. For example, further examination of the character relating to the mesosternal parapleura led to the detection of the fundamental structure now

utilized for the division of the Carabidae into the two sections as stated in the classifications of Leconte and Horn, based upon the extension of the mesosternal epimeron in the direction of the coxae. The other two discoveries of these systematists, who have given us our present arrangement, and probably the most natural that can be devised, relate to the existence of one or two supra-orbital setae, extremely significant in the second subdivision of the family but of no value in the first. The second is the presence or absence of a postero-external elytral plica.

The Harpalinae, according to Casey, embraces all Carabidae in which the meso-epimeron fails to reach the coxae, in which the head bears but one supra-orbital seta, the mandibles devoid of any external setigerous punctures, the posterior coxae contiguous and the elytra without a posterior external plica.

Casey abandons the use of the structure of the male tarsi heretofore used in dividing the tribes into three genera and names a succession of tribes upon a more restricted character. The principal division is based upon the setae of the second labial palpal joint. This character apparently escaped the attention of Leconte and Horn who used it only in the separation of genera which appeared to be otherwise closely allied. A bisetose second labial palpal joint shifted the position of several important genera, one of which was the genus Agonoderus.

Casey describes the genus Agonoderus as:

The body oblong-oval, convex, generally pallid in color. Head short, eyes large and prominent, the oblique frontal foveae prolonged by a fine line which attains the eyes. Emargination of the mentum is deep, much more broadly parabolic than in the preceding genus and the bottom of the notch is sometimes sub-prominently arcuate at its middle, suggesting a rudimentary tooth. The mentum bears two long discal setae near the notch. The ligula is long, distinctly dilated at apex, paraglossae diverging, rather slender, concave and narrowly rounded or subacute at their apices. The labial palpi are only moderate in length, the second joint with two long anterior and single postero-apical setae, third joint slender, very gradually and more obtusely pointed and apparently not quite as long as the second joint. The inner lobe of the maxillae is strongly falciform, the inner fringe long and coarse, the last joint of the outer lobe rather long, very slender and gradually pointed distally and slightly arcuate. Sexual differences are more feebly developed than in any other genus of the tribe excepting the Tachistodes. The anterior tarsi of the male barely visibly more swollen than the female, though usually a little shorter and they bear beneath two series of long, slender, internally crenate and hyaline squamae, often difficult to observe. Middle tarsi unmodified. The abdomen bears some sparse pubiferous punctures. The last segment bears four apical setae in both sexes, the apex being slightly more lobiform medially in the male than in the female.

Fabricius described A. pallipes as:

Oblong, less convex, sometimes almost wholly pale, elytra with a wide black stripe, divided by the suture; disk of the thorax often with a large dusky spot; head black, antennae dark reddish brown, the basal joints and legs pale. Thorax with hind margin and shallow basal impressions finely punctured; hind angles obtuse. Elytra with deep smooth striae, intervals convex. Length 5-6 mm.

This translation was taken from Blatchley's Coleoptera of Indiana (1910). Casey (1914) in his memoirs describes it more fully being careful to note the characteristics upon which *A. pallipes* is differentiated from *A. comma*. Casey describes it as:

> The body rather stout, convex, oblong-oval, rufo-testaceous, the head piceous-black, the middle of the vertex feebly pallescent, the antennal triangle pale, pronotum with a large transverse central blackish area, elytra with a large common oblong black area, produced anteriorily though seldom attaining the base and with the sutural interval rufo-piceous; under surface black except the sides of the prosternum and the epipleura; legs very pale; head smooth, large but little narrower than the prothorax, the vertex sometimes with a median puncture; eyes large and prominent; antennae stout, obscure testaceous, extending to the thoracic base; prothorax two-fifths wider than long, widest a little before the middle, the sides rounded, becoming oblique and straight posteriorily; apex truncate with very obtuse obliterated angles and a little wider than the base, which is arcuate-truncate, with obtuse but rather well-defined angles which are only slightly blunt at their apices; surface strongly declivous laterally, the edges very finely reflexed; median stria distinct but anteriorily abbreviated, the obsolete anterior impression punctureless; base sparsely but strongly punctured from side to side, more obsoletely medially, the foveae vague and feeble; elytra one-half longer than wide and two-fifths wider than the prothorax, parallel, with distinctly arcuate sides and sub-circularly rounded apex, sinus vestigial; striae deeply impressed, the scutellar short though generally distinct, deep; intervals convex; discal puncture behind apical third; hind tarsi very stout, piceous, fifth joint fully as long as the first two. 5.3-6.5 mm.

Economic Literature

A review of the economic literature shows very little work done on the biology of the corn seed beetle, *A. pallipes* Fab., although the insect was described by Fabricius in 1795. Forbes (1905) states that it was first recognized as a pest injurious to planted seeds in 1883 when a number of the beetles were found buried in the germ of seed corn. They were sent to the Bureau of Entomology for identification.

The adults are present in such large numbers in fields that, with optimum conditions, severe damage is done to the planted corn seed and in several cases there has been nearly 100 per cent loss.

Riley (1880) reports that *A. pallipes* was sent to the Bureau of Entomology when it was found swarming in great numbers in a field containing many egg pods of the Rocky Mountain locust and was thought to be feeding upon the eggs. This report was the first mention of the economic importance of the beetle.

Only two reports have been found giving actual figures on the probable loss due to injury and infestation in the field. One of these reports, Howard (1904), was from Texas when a number of specimens together with samples of sprouting grains were sent to the Bureau of Entomology showing some injured grains. Observations showed as many as 20 adults to a kernel and with an infestation so great in the field that, out of 60 acres, less than five acres were expected to be saved.

Another report, Swenk (1925) was received from Nebraska where the adult of this species along with the western corn root worm, Diabrotica longicornis, threatened to destroy a 70-acre field. Severe infestations have been reported over several counties of Nebraska. Swenk (1921) reports an abundance of beetles in Nebraska from Lancaster to Hall counties and south to Fillmore county.

Damage to planted popcorn southeast of Manhattan was reported a few years ago after the beetles had been found eating kernels following a flood over this area.

Forbes (1896) reports that Huber (1883) sent to the Bureau of Entomology and Plant Quarantine grains of corn in which he found the beetles buried. The bureau reports they received the beetle during the summer of 1885 with the information that it was injuring corn by gnawing into the seed and eating the sprouts.

Forbes (1896) reported that the beetle, until 1883, was thought to have been carnivorous, but, upon the examination of the stomach contents of a number of beetles, found both animal and vegetable matter. Forbes, according to Flint (1918), found upon examination of the contents of the alimentary tract of beetles taken in a field infested with chinch bugs that about one-fifth of the food of A. pallipes was derived from chinch bugs. Flint (1918) suggested that perhaps A. pallipes ate only the dead bugs and moulted skins.

The Insect Pest Survey contains a great many notes pertaining to the occurrence of the adults throughout the year. Frequently the records are merely reports of flights observed in certain localities throughout the United States.

MATERIALS AND METHODS USED

Work on the biology of the corn seed beetle was started before the spring flights in 1937 and continued until May, 1938. Work was started early in the year so that the adults coming out of hibernation could be obtained easily for purposes of study. Large numbers of beetles can be obtained most years in the early spring during their flights in the day or at trap lights at night.

The experiments were planned to work out the life cycle, hibernation, distribution, feeding habits, morphology, and to make observations on the general bionomics and ecology of the species.

Few references to the literature on the biology of the adults and larvae were available. A considerable amount of time was spent finding a medium in which the beetles would live and in which they would oviposit. A great many methods were attempted, but with little success, in an effort to get the females to oviposit eggs for rearing purposes.

The adults were obtained by capturing them during diurnal or nocturnal flights, by digging a few inches beneath the soil in fields previously planted to corn, and along river bottom land where a flood had left a layer of large cakes of packed sediment.

These adults were taken to the insectary and placed in gallon jars half-filled with moist soil. By keeping them in the jars, the adults were available at all times when needed.

Several methods have been tried in an attempt to secure eggs for rearing, but apparently the correct ecological conditions have not been attained for there has been no oviposition. This seems unbelievable. Since they are so prevalent out in nature, it would lead to the belief they would oviposit readily in any place, under almost any condition. Eggs were obtained for the drawing by dissection of gravid females.

The adults were difficult to find during the summer of 1938 as compared with the summers of 1935, 1936 and 1937. There were no large flights recorded in April, May or June. Only one or two adults were noticed at the lights on the nights under observation. Sedgwick county likewise did not have large flights as in other years. Normally great numbers came to the lights in that county.

Larvae, however, were plentiful and easily found. Two hundred and sixteen larvae were collected in a field that had been planted to brome grass. These were found a few inches below the surface of the soil during the months of March, April and May, 1938. Many pupated but had not emerged as adults at the time of writing of this paper.

In experiment one, jelly glasses were used half-filled with moist soil into which was placed a little wire cage. This cage allowed the beetles plenty of room, yet restricted the amount of soil which was to be searched for eggs. The activity of the adults prohibited the use of this cage. They quickly escaped by digging beneath the wire. Twenty of these cages were used but soon were abandoned because the adults escaped so easily.

A number of females were confined in vials with black paper in the bottom, in experiment two, in hope they could be induced to oviposit on the dark surface. There have been instances where females of certain Lepidoptera were induced to oviposit on dark surfaces. Twenty vials containing one female each were used and left until the beetles died.

In experiment three, salve boxes about half-filled with moist soil were used in an attempt to induce the beetles to deposit eggs. Two hundred five of these boxes containing one female each were used. These beetles were collected at lights and near a drainage ditch at the Kansas State College agronomy farm. The beetles were left in these boxes and examined, and as soon as all were examined, the procedure was repeated. This examination took place over a period of time extending from May 10 until June 15, 1937. This period was shortly after the adults had been observed to mate. Most of the adults had died during this period of little over a month, and those that had not were discarded.

On June 27, 1937, while collecting five miles south of Manhattan along the Kansas River bottoms, numerous adults were noticed between the blocks of silt left by a flood. These blocks were very wet and heavy. Fifty adults were captured and taken, along with a large quantity of this soil, back to the insectary in order to simulate the natural habitat of the beetles. Some of the soil and these beetles were placed in jars and left thirty days.

Two types of ground cages were used in experiment four in an attempt to get the females to oviposit. These cages are shown in Plate VII. One hundred beetles were placed in two large square cages and 20 were used in the small round ones, which were sunk into the ground nearly a foot so the beetles would not dig out beneath them and escape. The cages were watered twice a week.

Forty-eight larvae were acquired during June, 1937, by digging a few inches into soil that was quite moist. Most of them were taken at the agronomy farm along a drainage canal in fields that previously had been planted to corn. These larvae were kept in the insectary in salve boxes.

Much work was done on the feeding habits of the beetles as they ate readily in captivity. Glasses and salve boxes were used primarily as containers for the food and beetles. These were filled with moist soil. The beetles and food were placed in the containers and examined frequently. In feeding experiment one, 54 seeds were used in 27 jars, two grains of corn, one white and one red to a jar. The beetles were kept in the jars until they died.

In feeding experiment two, all white corn was used. Seventy grains of corn were used in 35 jars. One-half of the kernels were soaked 24 hours while the other half were not soaked at all. Two beetles to a jar were used.

In experiment three, 70 grains of soaked kafir and 35 grains of soaked white corn were used in 35 jars with 70 beetles and left for one week.

In experiment four, 40 grains of sweet corn soaked 24 hours were used in 20 jars with 40 beetles.

In experiment five, 18 pumpkin seeds were used in 18 jars with 36 beetles, 18 squash seeds were used in 18 jars with 36 beetles, and 24 watermelon seeds were used in 24 jars with 48 beetles. These beetles were left in the jars until they died.

Other feeding experiments included the use of blood-meal, tankage, and other beetles.

The larvae for the drawings and photographs were obtained from the agronomy farm in June, 1937, and preserved in 70 per cent alcohol. The adults used for the morphological study were captured in a light trap maintained by the Bureau of Entomology and Plant Quarantine. They were preserved in 70 per cent alcohol. Only females were used in the study.

The beetles were first boiled in KOH in preparation for the study. This turned the beetles black, so it was necessary to clear them partially in order to locate the true sutures. The clearing solution was made from potassium chlorate and concentrated sulphuric acid. These two chemicals were mixed and after chlorine had been liberated a small amount of alcohol was poured over the mixture. The beetles were then placed in the solution and allowed to stand. This solution cleared them sufficiently within a few hours to locate the sutures.

Observations on the hibernation were made periodically throughout the winter of 1937-1938 by going directly into the field. Many rocks, old trash and driftwood were turned over. In several cases, the author dug along the banks of a drainage canal at the agronomy farm. Beetles were found frequently under the old trash and logs.

Locality notes were taken from the Kansas State College collection, the Dr. Knaus collection, the Kansas University collection and from the author's observations and collections during the last half of the year 1937 and the first half of the year 1938.

DISTRIBUTION

Forbes (1896) states that A. pallipes ranges throughout the United States and Canada. The writer found them reported from fourteen states--from New Hampshire on the east to Washington and Oregon on the west--with particular abundance throughout the mid-central states near the Mississippi valley.

Leconte (1868) states that A. pallipes is abundant throughout the southern states.

Its distribution over Kansas also is very general having been taken or reported from nineteen counties in all four sections of the state. They have been recorded from Jewell county in the north tier of counties; Clark, Harper, Barber, Sedgwick, Sumner, Butler and Cowley counties in the south section; Wilson, Crawford and Bourbon counties in the southeast corner; Finney, Wallace and Thomas counties in the western section, and Dickinson, Riley, Shawnee, Pottawatomie and Leavenworth counties in the eastern section of the state.

Specimens in the Kansas State College collection were taken from Shawnee, Riley, Wallace and Thomas counties. The University of Kansas had no specimens in the collection taken from Kansas. However, they had one specimen taken at St. Thomas, Ontario.

HABITAT STUDIES

The adults of A. pallipes can be collected throughout the year. They hibernate as adults beneath trash, driftwood cornstalks, and leave their winter quarters at the first warm day. Apparently they preferred a moist habitat, both in the adult and larval stages, as most of them collected in the field were from soil that was very moist or from localities that had recently been flooded.

Plates V and VI are examples of summer habitat. Both are flood plains about five miles south of Manhattan near the Kansas river. Larvae, pupae and adults were found in the cracks and in the colloidal blocks formed by this waterlogging. The adults were obtained by turning over these blocks of sediment or by using an aspirator on a collecting jar along the cracks.

It was observed that on hot days during the summer of 1937 the beetles could be found around the top of these cracks early in the morning, but as the sun climbed higher they would go farther down into the cracks until about noon when they left the cracks and were found under the blocks. During late afternoons as the sun set, they came slowly to the top.

The larvae and pupae were obtained by breaking open these waterlogged blocks. Adults were found under cow dung, trash, old cornstalks, around the base of old cornstalks, and below the surface of the soil near a drainage canal.

The larvae have been collected about two inches below the surface of the ground near rotting stalks in damp ground.

On March 22, 1937, the adults were found in a west-facing talus slope of a drainage canal near the agronomy farm during the afternoon. These adults were located on the west-facing slope to get the benefit of the afternoon sun which was very warm although the air was very chilly and a crisp wind was blowing.

PARASITES AND ENEMIES

There was no mention in the literature of the parasites affecting the corn seed beetle, and only one reference to the enemies of the corn seed beetle was found.

Flint (1914), in writing of the capture of living insects by the cornfield ant, *L. niger americanus*, states that *A. pallipes* was readily killed.

The author collected two hymenopterous parasites of the family Braconidae which were reared from larvae collected at the agronomy farm. These two parasites emerged May 5, 1938, but have not been identified to species.

TRAP LIGHT STUDIES

The adults are positively phototropic; however, they fly during the day as well as at night. More than one pint of beetles was taken from a half-gallon trap light on July 21, 1937 at Garden City, Kansas. As much as one quart of beetles from a half-gallon trap light has been reported.

A count was made to determine the sex ratio of adults coming to lights. Basing this count on 235 specimens, a ratio of one male to one and three-tenths females was obtained.

Their flights at Manhattan have been reported from February until September. The earliest flight recorded at Manhattan was in 1938 when the adults were seen flying during a warm day in February. In 1937 they flew near Manhattan on April 1. The last recorded flight at Manhattan during the summer of 1937 was taken from light trap collections on September 26. An examination of the daily collection record of the trap material, diagrammed in Plate I, will reveal the fact that the peaks of flight in 1935 and 1936 occurred from the middle of July until the first of August.

Observations indicate they do not fly below 53 degrees F. and as the temperature lowers to that point their flights stop abruptly. For example, on April 1, 1937, the adults were first noticed flying in the afternoon between the hours of 3:00 and 5:00 p.m. The temperature during those hours was exactly 53 degrees F. On March 6, the beetles were plentiful around the lights of Aggieville up to 10:30 p.m. when they started dwindling in great numbers. A check of the temperature gave a reading of 65 degrees F. at 8:00 p.m. and 53 degrees at 10:00 p.m. and 51 degrees at 11:30 p.m. In contrast to this, on May 7, the beetles were still coming to the lights when the author went home at 11:30 p.m. A check of the temperatures for that night gave a minimum of 56 degrees F.

Counts of A. pallipes coming to a light trap in Lincoln, Nebraska, which was conducted for gathering data on cutworm moths, covers a period from June to September, 1935; May to August, 1936.

The estimations were made by counting the number of beetles that filled a vial, and, by refilling the vial and multiplying the number of beetles one vial held by the total number of times the vial was refilled, the total number of beetles could be computed. These counts were made on consecutive nights. The temperature and humidity readings were recorded at 7:00 p.m. Adults coming to lights appear to be affected by the relative humidity and temperature curves.

A summary of the activities of the beetles which flew to lights during the summers of 1935 and 1936 at Lincoln, Nebraska, indicates that the numbers of beetles coming to lights when certain temperatures prevailed corresponded closely to the observations recorded at Manhattan during the summer of 1937. Plate I shows the numbers taken in flight in 1936 were greatest when the temperature averaged 94 and the humidity averaged 28. In 1935 the temperature averaged 85 and the humidity 50 for the 15 largest flights. These flights were much smaller in number than those in 1936, possibly due to the lower temperature and high humidity. Flights were large at Manhattan and at Garden City during July and August. The average temperature and humidity for the ten highest flights were above 90 and below 30 respectively.

Table 1 is a survey of the 15 largest flights and shows that the beetles tend to fly to the light on the nights when the temperature is on an ascending curve and the humidity is on a declining curve.

Table 1 shows that the largest single flight recorded for 1936 occurred the night of June 8. The temperature for the night was 92 degrees F. and the humidity

Table 1. Fifteen largest flights recorded for 1936 and the climatological trends

Number Beetles	Temp. Prev. Day	Temp. Day Recorded	Temp. Foll. Day	Humid. Prev. Day	Humid. Day Recorded	Humid. Foll. Day
103,750	72	92	63	56	44	52
34,120	91	94	99	42	27	11
25,000	99	91	94	23	42	27
17,000	87	89	93	38	23	18
15,360	93	106	103	18	10	11
11,920	98	96	101	25	31	19
9,740	101	84	88	19	49	30
7,856	96	101	103	31	19	13
6,480	81	93	80	54	25	34
5,616	88	100	94	30	16	21
5,420	103	101	101	13	19	21
4,360	105	102	101	17	20	19
3,960	107	81	93	17	50	25
3,880	101	95	95	18	28	28
3,715	100	94	108	16	21	12

44 per cent, with a total of 103,750 beetles. The previous night's temperature had been 79 and the humidity 56. The second largest flight was 34,120 which was recorded the night of June 27, with temperature reading of 94 and humidity 27. The preceding day had a temperature of 91 and a humidity of 42. Twenty-five thousand beetles were collected for the third largest flight the night of June 26, with a temperature of 91 and a humidity percentage of 42. The previous night's temperature was 99 and the humidity 23. The fourth highest flight recorded was July 1, when 17,400 beetles came to lights that night with temperature of 89 and humidity of 23. The previous night's reading was 89 degrees and 30 per cent humidity. The fifth highest record was 15,360 beetles on the night of July 3, with a high temperature of 106 and a humidity of 10. This was a rise of 13 degrees over the previous night and a drop in humidity of eight per cent. The sixth highest reading was recorded on July 12, when 11,920 beetles came to the light with temperature of 96 and humidity of 31. The previous night's temperature was 98 and the humidity was 25. The seventh highest flight occurred the night of July 20, when 9,740 beetles came to lights with the temperature reading 84 and humidity 49. The preceding reading was 101

degrees and 19 per cent humidity.

The eighth highest recorded flight was 7,856 beetles on the night of July 13, with the temperature at 101 and the humidity at 19. The preceding night's temperature was 96 and the humidity 31.

Six thousand four hundred eighty beetles were recorded for the ninth highest night's collection on July 28 with temperature of 93 and humidity 25. The temperature for the preceding night was 81 degrees and the humidity was 54. The tenth highest record occurred on the night of July 22, when 5,616 beetles were taken at the trap light with temperature of 100 and humidity of 16. The temperature of the preceding night was 88 and humidity 30. The eleventh highest reading was 5,420 on July 16. Temperature that night reached 101 and humidity climbed to 19. The previous readings were 103 degrees and 13 per cent. The twelfth highest record, 4,360 beetles, was recorded on July 18, with temperature at 102 and humidity at 20. The readings on the previous day were 105 and 17. There were 3,960 beetles in the flight on the night of July 27 to rank thirteenth. The temperature was 81 and the humidity 54, following a night on which the temperature reached 107 and the humidity fell to 17.

The fourteenth highest record of flight was 3,880 on

July 6, with temperature and humidity readings at 95 and 28. The day previous had a temperature of 101 and a humidity of 18. July 23 ranked fifteenth with 3,715 beetles in flight with a temperature of 94 and a humidity of 21, following readings of 100 and 16.

A check of the trap light material shows there were many more beetles coming to the lights during the summers of 1936 and 1937 as compared with the numbers that came to the lights in 1935 and 1938. Over 300,000 were taken at the lights in 1936, and only 30,000 adults were collected in 1935. No actual counts were made in 1938, but adults flying to the lights were scarce.

Table 2 shows the highest recorded flight for 1935 occurred on September 12, when 3,624 beetles were collected with the temperature at 80 and the humidity 56. On the preceding night, the temperature reading was 73 and the humidity 49. This was 100,000 less than the all-time high of 1936.

The second highest flight, 1,996 occurred on July 27, with the temperature 99 and the humidity 33. Previous readings were 97 and 36. The third highest number recorded was 1,818 on September 14, with the temperature and humidity readings of 82 and 55 compared with 82 and 51 on the

Table 2. Fifteen largest flights recorded for 1935 and the climatological trends

Number Beetles	Temp. Prev. Day	Temp. Day Re-corded	Temp. Foll. Day	Humid. Prev. Day	Humid. Day Re-corded	Humid. Foll. Day
3,624	73	80	82	49	56	51
1,996	97	99	100	36	33	25
1,818	82	82	83	51	55	41
1,224	83	79	83	41	57	53
1,161	90	90	87	65	56	63
1,112	80	82	82	56	51	55
1,097	84	90	87	45	35	47
984	81	84	81	60	62	68
978	101	100	81	27	31	71
857	84	81	82	62	68	61
822	83	97	90	58	34	44
814	90	94	97	50	44	36
796	73	90	94	78	50	44
751	98	95	93	34	56	30
703	97	85	84	42	64	45

previous night. September 16 was listed as the fourth highest with 1,224 beetles in the catch. Temperature was 79 and humidity 57. The night before, the readings were 83 degrees and 41 per cent.

The fifth highest number was 1,161 on July 5, with temperature and humidity at 90 and 56. On the preceding night the temperature was 90 and the humidity 65.

The sixth highest was 1,112 on September 13, with the temperature 82 and the humidity 51. The previous readings were 80 degrees and 56.

July 14 ranked seventh highest with 1,097 beetles coming to lights. The temperature and humidity were recorded at 90 and 35. The preceding night had a temperature of 84 and humidity of 45. Eighth highest number of beetles was on June 14 when 984 adults came to the light. The temperature read 84 and the humidity 62. The preceding night had a temperature of 81 and a humidity of 60.

The ninth highest number, 972, was on the night of August 1, with a temperature of 100 and humidity of 31. On the preceding night the temperature was 101 and the humidity 27. The tenth highest flight occurred on the night of June 15 with temperature of 81 and humidity 68. Eight hundred fifty-seven beetles were recorded. The previous reading gave a temperature of 84 and humidity of 62.

August 5 ranked eleventh with 822 beetles and a temperature of 97 and humidity of 34. The readings on the preceding night were 83 and 58. The twelfth highest flight of beetles was on July 25, with temperature of 94 and humidity of 44. Eight hundred fourteen beetles were collected. On the night before, the temperature read 90 and the humidity 50.

July 24 was thirteenth with 796 beetles collected at the lights. The temperature was 90 and the humidity was 50. They were recorded at 73 degrees, 78 per cent on the night preceding.

The fourteenth highest flight recorded occurred on August 9 with 751 beetles. The temperature was 85 and the humidity 56. The night preceding, the temperature read 98 and the humidity 34.

The flight ranking fifteenth for the summer was 703 beetles on July 11. The temperature was 85 and the humidity was 64, compared with 97 and 42 on the previous night.

FEEDING HABITS

The feeding habits of the Carabidae are very diverse. Many of them feed on vegetation while others have a strictly carnivorous habit. The vegetative diet of Carabidae is principally seeds and tissues of grasses and grains. According to Forbes (1905), four genera of Carabidae, namely, Anisodactylus, Harpalus, Amara and Agonoderus, derive the greater part of their food from these sources. Many have been seen in the fall hollowing out grains of corn, especially on fallen ears or broken down stalks where decay or previous injury facilitated their work.

Pterostichus permundus was found eating away the side of a fallen kernel beginning at a point of previous injury. Pterostichus lucublandus was seen on fallen ears, eating into a number of grains leaving only a thin shell. Amara musculus Say was found among husks and on ears of standing corn. Platynus crenistraiatus hollowed out grains of corn while Agonoderus pallipes was found to be eating fallen grains of corn and those which had already sprouted.

Forbes (1905) also makes the statement that approximately 90 species of beetles have been identified as insects injurious to corn either in the larval or adult stages, and a few of them in both.

However, Forbes (1905) continues:

> Not more than a third of them need be mentioned in merely an economic list. If we do not attempt to distinguish for economic purposes between the different kinds of white grubs and wireworms which infest corn under ground the list so reduced will contain less than a dozen names.

The habits of the adults and those of the larvae are, in most cases, so widely different that instances are few in which we find both stages of the same insect infesting corn. Forbes (1905) also states:

"There is not a single case on record in which a similar injury is done to corn by both."

All beetle larvae injurious to corn live under ground and their injuries consequently are confined to the planted seed, roots, and the under-ground part of the stalk. The adults, on the other hand, may eat any part of the plant from the seed and roots to the silk and kernels of the ear.

Experimentation on the feeding habits of the beetle A. pallipes in relation to corn bears out the statements of Forbes. However, there were not enough larvae available to experiment extensively with them. The results of these experiments and the methods used are similar in that soaked and non-soaked grains were used, and usually two beetles were placed in each jar. The writer has found that the adults prefer the soaked grains to the non-soaked ones and that they will eat animal as well as vegetable matter. In no case, however, could they be induced to eat cucurbits. Nor did they eat the one legume tried.

In the first experiment when a total of 54 seeds were used, 27 grains of red corn not soaked and 27 grains of white not soaked, the results showed three red grains and three white grains injured or 11 per cent injury to each. In experiment two when one-half of the grains of corn were soaked, 27 soaked grains were injured while only three non-soaked grains were injured. In experiment three, there were 35 grains of soaked corn and 70 grains of kafir. The results showed 39 kafir grains injured and 16 white grains injured. This is a 55 per cent injury to kafir and 45 per cent injury to white corn.

Experiment four, in which 40 grains of sweet corn soaked 24 hours were used, showed 37 grains were damaged or 92 per cent injury.

The experiment in which several kinds of cucurbits were used gave no injury to any of them even after the beetles had gone many days without food. Likewise, in the experiment using the common garden snap bean, no injury was done by the beetle.

The experiments conducted using animal matter exclusively showed the beetles to be carnivorous and cannibalistic. The adults were induced to eat bloodmeal and tankage readily and at the first opportunity would attack and eat each other. Cannibalism was observed frequently in jars where a large number of beetles were confined. The adults were also observed to eat the dead beetles. However, their feeding was not confined to the weak nor to the dead beetles. There appeared to be no discrimination and no fighting back by the beetle attacked. Running away seemed to be their only defense.

DESCRIPTION OF THE INJURY

The type of injury to seed corn was found to be quite characteristic of the adult. They attacked, in turn, the radicle, cotyledon, plumule and proceeded inwardly into the endosperm, hollowed out the grain and left only the pericarp. Many seeds were found to be injured in this way. Kafir appeared to have no special point of attack, any place on the fruit being equally vulnerable. Even the pericarp of kafir was eaten.

Data on the larval injury is meagre both in literature and in experimentation. There is no mention in the literature as to the type of injury and food habits of the larvae. Several grains of wheat taken from salve boxes containing larvae had the centers hollowed out apparently by the larvae. This grain had sprouted but had withered after the attack. The grains had been put in the boxes in good condition. The injury to the wheat grain was accomplished by boring directly into the kernel and left only the coating and the few roots that had started growing.

LIFE HISTORY STUDIES

Egg

It is not known definitely when or where the eggs are laid. However, Forbes (1896) states the eggs are laid shortly after emergence of the adults in early spring.

Since larvae were found in the habitats which were damp or wet, it is the opinion of the writer that the eggs are laid in wet or moist soil. Of the many methods used to secure eggs none was successful. Approximately a thousand females were used in these experiments. Several eggs have been dissected from gravid females in early spring.

Larva

The larvae were abundant in the early spring in moist soil. They have been taken about two to five inches beneath the surface of the ground near a drainage ditch in the agronomy farm. Also they were collected south of the Hessian fly nursery near the college campus at the KSC insectary No. 2.

The larvae also were found in blocks of sediment that were still wet from flooding. These blocks had been formed after the flood had receded and the water was beginning to evaporate from the soil. Plates V and VI show examples of the type of ground and habitat in which they were found. The eggs hatch in about ten days but it is not known how long a time is spent in the larval stage. Two hundred sixteen larvae were taken in the months of March, April and May, 1938, from a pasture of brome grass. The first one pupated June 3.

Pupa

The pupae have been collected in waterlogged sediment blocks in the same locality as the larvae. The length of the pupal period has not been determined. The author had, at the time of writing, 147 pupae that had been in the pupal stage nearly a month. The first one to pupate was June 3, the last one June 30. These were from 216 larvae taken in March, April and May.

Adult

Forbes (1896) states that the adults hibernate and leave their winter quarters with the first warm days of spring. The eggs are laid shortly afterwards with the new generation emerging in June and July. He also says the adults can be found throughout the year and there is probability of more than one generation a year.

The author has found the adults hibernating under old logs, cow chips, rocks and among piles of old corn stalks. The adults left hibernation when the temperature reached a point conducive to flight, whether it was spring or winter months. They flew in February, 1938, at Manhattan, Kansas. Soon after emergence the beetles mated. They were noticed mating May 6, 1937, and the first egg was dissected from a female on May 7, 1937. This egg failed to hatch probably because of immaturity.

DESCRIPTION AND MORPHOLOGY

The morphology of the adult of A. pallipes Fab. does not differ greatly from the typical ground beetle used in a great many morphology classes. The head capsule, both dorsal and ventral aspects, ventral aspects of the thorax and abdomen were worked out in detail to do three things; first, to show the characters upon which the tribe and genus is based; second, to present an accurate drawing of a Carabid for reference, and third, to compare the modifications of the mandibles with truly carnivorous beetles, Calosoma scrutator, and true vegetarian, Harpalus caliginosus.

The front leg of A. pallipes was drawn together with a front leg of a species of Clivina, with which the former is associated, to compare two types of burrowing legs--Plate IV, Figs. 2 and 5.

It was necessary to boil the beetles in KOH and then bleach them to accentuate the sutures distinctly enough to follow them. Only females were used.

Egg

All descriptions for the egg were taken from dissected females, and apparently have no distinguishing characteristics that are very noticeable. They are pearly white and oval in shape--Plate II, Fig. 2. They are 1 mm. long by .5 mm. wide. There are no impressions from the egg tube on the chorion.

Larva

The larva of A. pallipes is small, being about 15 mm. in length when grown. The color shades from yellowish brown head and thorax to a yellowish white abdomen. Setae are conspicuous over the entire sclerotized areas of the body. The body consists of a prominent head, thorax and nine segmented abdomen--Plate II, Fig. 4. The mandibles are prominent but do not decussate.

Pupa

The pupa of A. pallipes is about 4 mm. in length by 1.5 mm. in width across the thorax--Plate II, Fig. 1 and 3. The color is pearly white when first in the pupal stage, later turning a light yellowish white. Two eye spots are prominently black, with the wing pads and legs conspicuous. The mandibles are yellowish brown and show prominently on the head.

Adult

Blatchley (1910) describes the adult as:

> Oblong, less convex, sometimes almost wholly pale; elytra with a wide black stripe, divided by the suture; disk of the thorax often with a large dusky spot; head black. Antennae dark reddish-brown, the basal joints and legs pale. Thorax with hind margin and shallow basal impressions finely punctured, hind angles obtuse. Elytra with deep, smooth striae; intervals convex, length 5-6 mm.

MORPHOLOGY OF ADULT

The dorsal view of the head capsule reveals the fact that it is three times wider posteriorily than when measured across the labrum; one-sixth longer than wide, (Plate III, Fig. 1). The labrum is slightly wider than long with six anterior setae, the two outside setae are longer than the second pair which pair, in turn, is longer than the center two, and with seven setae along the disto-lateral edges; clypeo-labral suture (CLS) prominent; anterior edge of the labrum slightly convex, narrower than the clypeus.

The anteclypeus (AC) is two and one-half times wider than long, one and one-half times wider posteriorily than anteriorily; two long setae latero-cephalad. The anterior mandibular articulations (AMA) are prominent. The clypeo-labral suture is prominent, meeting the epistomal suture about one-sixth the distance from the lateral edges.

The post clypeus and frons are about equal in length. The anterior tentorial pits (ATP) are prominent along the epistomal suture (ES) and which suture reaches the oblique frontal foveae which is prolonged by a fine canaliculation that reaches the eyes. A sub-ocular suture is present. The eyes are prominent.

Two prominent supra-orbital setae are present. The occipital suture (OCS) is about one-fourth the distance between the foramen magnum and the clypeal suture (CS) encircling the dorsal part of the head to end ventrally posteriorily to the submentum, (SM, Fig. 2) and forming an internal ridge to strengthen the epicranial wall.

The postoccipital suture (POS) lies on the extreme posterior part of the cranium closely surrounding the foramen magnum dorsally and laterally and fusing with the gular sutures (GUS).

Posterior mandibular articulations (MA) are located distally and are prominently U-shaped. The submentum lies between the maxillary cardines (CD, Fig. 3) and is fused with the gula (GU) with no suture present between them; convex distally at the attachment to the mentum.

The posterior tentorial pits are located on the terminal ends of the gular suture and the juncture of the gula with the submentum.

The gula lies proximal to the labium (Fig. 4) and is narrowed at the distal end and widens at the middle until one-third the width of the epicranium proximal to the occipital suture. The occipital suture ends posteriorily to the submentum one-half the distance from the submentum to the foramen magnum.

The ligula lies between the labial palpus and is a distinct part of the labium; long, distinctly dilated at the apex. The glossae (G) are fused, dilated at the tip and narrowed basally; apex dentate with two distal setae. The paraglossae (PG) are divergent, slender, concave and narrowly rounded at their apices.

The labial palpi (PP) are moderate in length, the second joint with two anterior and one posterior apical setae; third joint slender, very gradually obtusely pointed and not quite as long as the second; first joint small and elbowed. The palpiger (PAG) is club shaped; dilated apically; two-thirds as long as the second joint. Membranes between the palpal segments are distinct.

An emargination of the mentum (M) is deep, somewhat arcuate in the nock; broadly parabolic; laterally convex, two times as wide as long, bearing two long setae near the nock; basal edge concave.

The submentum (SM, Fig. 4) is apically convex, obliquely truncate; lies between the maxillary cardines; fused with the gula; bears four long setae paired equidistant from the edges. The lateral setae shorter than the mesal ones.

The lacinia (LAC, Plate III, Fig. 3) is strongly falciform with the inner surfaces coarsely fringed; the galea (G) longer than the subgalea, (SBG), very slender and gradually pointed at the tip; arcuate. Subgalea is distended apically; slightly shorter than the galea. The palpus (PP, Plate III, Fig. 4) is four jointed, stout, gradually pointed distally; second joint slightly arcuate; third joint distended apically and shorter than the second and fourth joint; distal joint tapered apically, set with short setae; stipes (STP) twice as long as wide, nearly as long as the lacinia; two long setae laterally. The cardines (CD) are at right angles to the stipes; roundly elbowed with the articulating surface pointing posteriorily.

The mandibles (Plate III, Fig. 5) are stout, 1 mm. in length; slightly decussating; incisors are prominent, ridged; molars (MO) are distinct about one-fourth the distance from the base; mandibles are heavily fringed posterior to the molars. Anterior and posterior mandibular articulations (MDA) are prominent.

The prothorax, Plate IV, Fig. 3, is two-fifths wider than long; widest part a little anterior to the middle; terga strongly reflexed, sides rounded, becoming oblique and straight posteriorily; apex truncate with very obtuse angles, a little wider than the base which is subprominently convex, with obtuse angles. The prosternum (PS) is strongly arcuate anteriorily. The proepisternum (PES) is strongly convex laterally; oblique mesally along the prosternum; slightly wider anterior to the middle; coxal cavities (CC) closed behind; the proepimeron (PEM) is triangular lying posterior to the coxae.

The mesothorax, Plate IV, Fig. 3, is twice as wide as long. The anterior margin concave. The mesoepisternum (MES) is nearly trapezoidal in shape meeting the mesoepimeron (MEM) at an oblique angle. The mesoepimeron is a narrow sclerite lying posteriorily to the mesoepisternum and does not reach the coxal cavities--which character is one that distinguishes the subfamily Harpalinae from the other subfamilies--The mesosternum (MS) is between the mesoepisterni. The posterior edge houses the anterior half of the coxa (CC), and is triangular in shape.

The metathorax, Plate IV, Fig. 4, is twice as wide as long. The anterior margin of the metathorax contains the posterior half of the coxa. The metaepisternum (METES) is about twice as long as the widest part which part is the anterior half. The metaepimeron (METEM) runs posteriorily dorsad to the posterior half of the metaepisternum and makes a right angle turn to end posteriorily to the metaepisternum. The first segment of the abdomen is split by the antecoxal pieces. The antecoxal pieces are divided by a sternal suture which crosses the thoracic suture at right angles.

The abdomen, Plate IV, Fig. 1, consists of six segments. Each segment bears some sparse pubiferous punctures. The first segment of the abdomen is divided by the antecoxal pieces. The last segment bears four apical setae (S) in both sexes. The apex is lobiform medially.

COMPARISON OF MANDIBLES

The mandibles of A. pallipes appear to be intermediate between the strictly carnivorous species of carabid, Calosoma scrutator, and that of a true vegetarian, Harpalus caliginosus. These three Carabidae, diverse in their feeding habits, have mandibles concomitant with their distinct type of feeding. For example, Calosoma scrutator, a carnivorous beetle has long slender mandibles with sharp incisors for grasping prey. Harpalus caliginosus, the other extreme, with a vegetative habit has short stout mandibles for crushing grains and Agonoderus pallipes a vegetarian and a carnivore has mandibles intermediate between that of Harpalus and Calosoma.

Plate III, Fig. 6, shows the mandibles of the carnivorous searcher, Calosoma. The mandibles are long and slender being about three times longer than wide. The incisors of Calosoma are long and slender, used for grasping prey, and are prominently decussed when at rest. The molars lie well toward the back with a heavy fringe running from the base toward the tip about two-thirds the length of the mandible.

Plate III, Fig. 7, shows the mandibles of Harpalus with its crushing molars for grinding seeds and grains. The incisors are short. A fringe lies posteriorily to the molars as in Agonoderus. The mandibles of Harpalus are short and stout being not half as long as wide as compared to Calosoma mandibles which are three times longer than wide.

Plate III, Fig. 5, shows the mandibles of A. pallipes a beetle that is both a carnivore and vegetarian. The mandibles are stouter than those of Calosoma but not as stout as Harpalus, being about twice as long as wide. The incisors are prominent but heavier than those of Calosoma. The molars are small compared to Harpalus yet have a larger grinding surface than Calosoma. A fringe posterior to the molars is prominent.

COMPARISON OF LEGS

The legs of Agonoderus pallipes and Clivina sp., Plate IV, Fig. 2 and 5, are both of the fossorial type. However, the leg of Agonoderus is much longer than that of Clivina. The femur of Clivina is very short while that of Agonoderus is more slender and leads to the belief Agonoderus may be adapted to running swiftly along the ground. The short stubby legs of Clivina make it harder for this species to do this. Both of the beetles have legs with coarse spines and digging organs. Clivina has digging organs much heavier than Agonoderus.

SUMMARY

The literature of the corn seed beetle has been confined largely to reports of injury and to taxonomic studies of the group to which it belongs.

The work on the biology and ecology of the corn seed beetle was started before the spring flight of 1937 and continued until the summer of 1938. The experiments were designed to work out the life cycle, hibernation, distribution, feeding habits, morphology and to make observations on the general bionomics of the species.

The author has found that A. pallipes ranges throughout the United States and Canada. They have been reported from fourteen states with particular abundance throughout the mid-central states near the Mississippi valley. Its distribution over Kansas also is very general, having been taken or reported from 19 counties.

The adults can be collected throughout the year. They hibernate as adults beneath trash, driftwood, and cornstalks, and leave their winter quarters on the first warm day. Apparently they prefer a moist habitat, in both the adult and larval stages, since most of the collections were from ground that was very moist or from localities that

had been flooded recently.

Prior to 1883, the adult was thought to be strictly carnivorous. Forbes (1896) found both animal and vegetable matter upon dissection. The author found the adults would eat corn, kafir, wheat, bloodmeal, tankage, but could not be induced to eat cucurbits nor legumes. There appeared to be a preference shown for corn or kafir that had been soaked 24 hours, over the grains that had not been soaked. Damage of 92 per cent was observed in one experiment using sweet corn that had been soaked. Cannibalism has been observed frequently.

The type of injury to seed corn was found to be characteristic of the adult. They attacked, in turn, the radicle, cotyledon, plumule, and proceeded inwardly into the endosperm, hollowed out the grain and left only the pericarp.

Forbes (1896) states the adults hibernate and leave their winter quarters in early spring and that the eggs are laid shortly afterwards with the new generation emerging in June and July. The adults have been noticed mating in early May. Since the larvae and pupae have been found in moist soil and in localities that had been flooded, the adults probably seek this habitat in which to oviposit.

The larvae have been found in abundance in early spring and late fall leading to the belief there are two generations a year.

The eggs, which are laid in the spring and fall, hatch in about ten days. The larvae, as well as the adults, overwinter. The larvae pupate in little earthen cells a few inches beneath the soil.

Two enemies of the corn seed beetle have been observed. One a parasite of the larvae and the other one predacious on the adult.

The adults are positively phototropic, but fly during the day as well as to lights at night.

A count made to determine the sex ratio of adults coming to lights showed a ratio of one male to one and three-tenths females.

Their flights have been recorded from February until September at Manhattan, Kansas.

Observations indicate the adults do not fly below a temperature of 53 degrees F., and as the temperature lowers to that point their flight stops abruptly.

A count of trap light material for the months of May to August, 1936, and from May to September, 1935, showed the peak of flight occurring during the month of July. A high of 103,000 beetles for one night's flight to trap lights has been recorded.

The number of beetles coming to lights is apparently affected by the temperature and humidity; for, as the temperature rises and the humidity drops, the number of beetles in flight increases.

ACKNOWLEDGMENT

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Acknowledgment is also due Mr. Robert Cotton for the drawing of the adult and pupa, and to Mr. Floyd Hanna, the college photographer, for the photographs used. He wishes also to thank Prof. D. A. Wilbur for his helpful criticisms of the morphology of the adult.

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EXPLANATION OF PLATE I

Fig. 1. Collections of *A. pallipes* at a trap light in Lincoln, Nebraska for the year 1935 with temperature and humidity records for each night.

Fig. 2. Collections of *A. pallipes* at a trap light in Lincoln, Nebraska for the year 1936 with temperature and humidity records for each night.

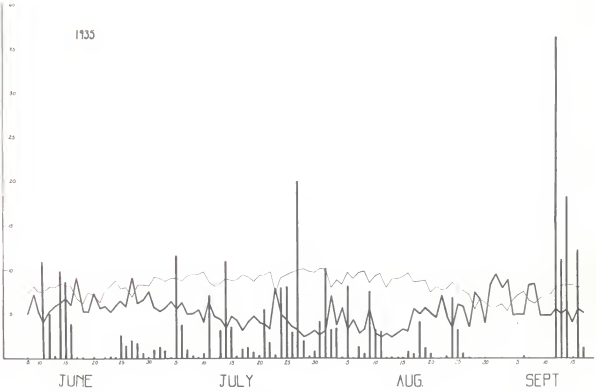


Figure 1

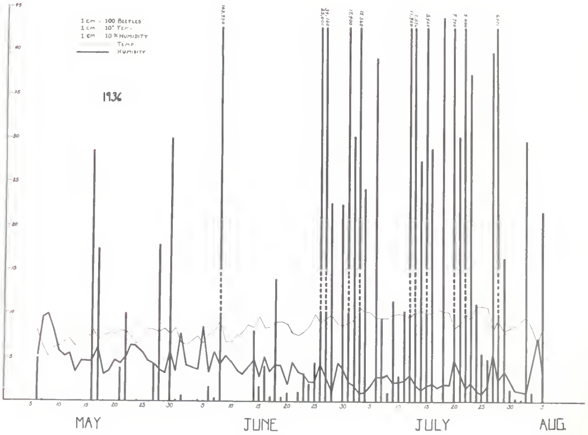


Figure 2

EXPLANATION OF PLATE II

Fig. 1. Pupa--ventral aspect
Fig. 2. Egg
Fig. 3. Pupa--dorsal aspect
Fig. 4. Larva
Fig. 5. Adult

PLATE II

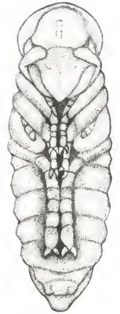


Figure 1

Figure 2

Figure 3

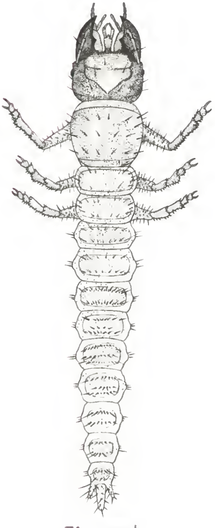


Figure 4

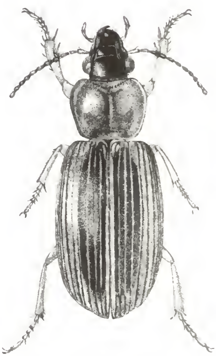


Figure 5

EXPLANATION OF PLATE III

Fig. 1. Head capsule--dorsal view
AC--anteclypeus
AMA--anterior mandibular articulation
ATP--anterior tentorial pit
CLS--clypeolabral suture
CS--clypeal suture
ES--epistomal suture
OCS--occipital suture
POS--post occipital suture

Fig. 2. Head capsule--ventral view
GU--gula
GUS--gular suture
MA--mandibular articulation
OCS--occipital suture
PTP--posterior tentorial pit
SM--submentum

Fig. 3. Maxilla
AC--articulation
CD--cardo
G--galea
LAC--lacinia
PP--palpus
SBG--subgalea
ST--stipes

Fig. 4. Labium
G--glossae
M--mentum
PAG--palpiger
PG--paraglossa
PP--palpus
PTP--posterior tentorial pit
SM--submentum

Fig. 5. Mandibles--<u>A. pallipes</u>
IN--incisors
MDA--mandibular articulation
MO--molars

Fig. 6. Mandibles--<u>Calosoma scrutator</u>
IN--incisors
MA--mandibular articulation
MO--molars

Fig. 7. Mandibles--<u>Harpalus caliginosus</u>
IN--incisors
MA--mandibles
MO--molars

PLATE III

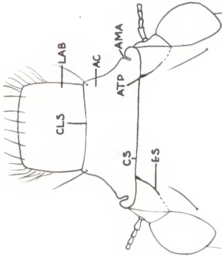
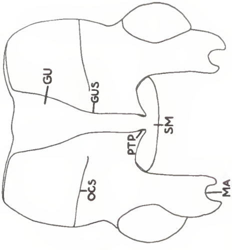


Figure 1



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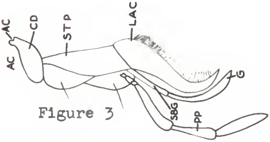

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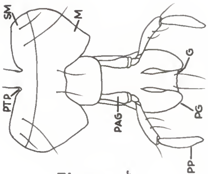

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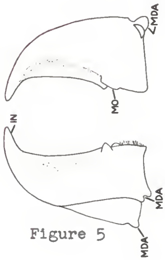

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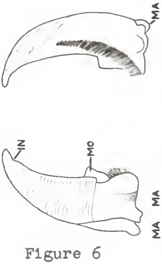

Figure 6

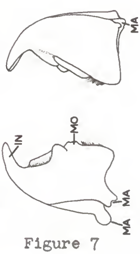

Figure 7

EXPLANATION OF PLATE IV

Fig. 1. Abdomen--ventral aspect
EPE--epipleura of the elytra
S--setae
Fig. 2. Front leg of A. pallipes
CO--coxa
FE--femur
TAR--tarsi
TB--tibia
TR--trochanter
TRO--trochantin
Fig. 3. Prothorax--ventral aspect
CC--coxal cavity
PEM--proepimeron
PES--proepisternum
PS--prosternum
Fig. 4. Meso- and metathorax--ventral aspect
CC--coxal cavity
MEM--mesoepimeron
MES--mesoepisternum
MS--mesosternum
METEM--metaepimeron
METES--metaepisternum
METS--metasternum
Fig. 5. Front leg of Clivina sp.
CO--coxa
FE--femur
TB--tibia
TAR--tarsi
TR--trochanter

PLATE IV

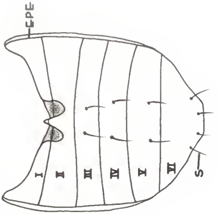

Figure 1

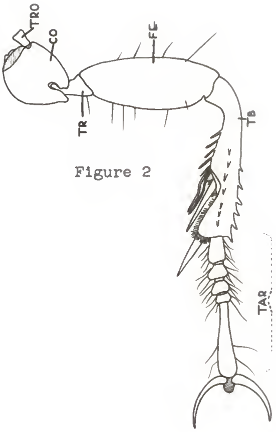

Figure 2

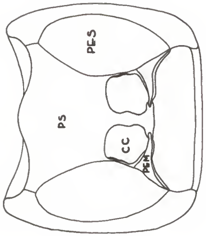

Figure 3

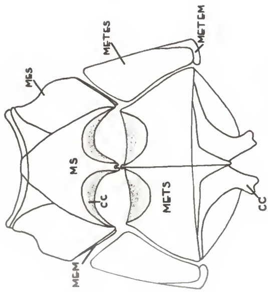

Figure 4

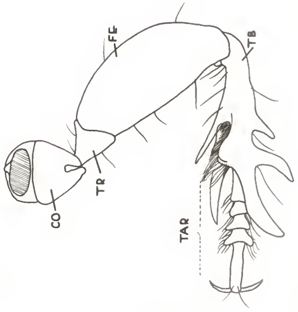

Figure 5

EXPLANATION OF PLATE V

Fig. 1. Close-up view of a summer habitat of *A. pallipes* in ground recently flooded.

PLATE V

EXPLANATION OF PLATE VI

Fig. 1. The same locality as Plate V, but showing the general surroundings of the habitat.

PLATE VI

EXPLANATION OF PLATE VII

Fig. 1. Type of cages used in
oviposition studies.

PLATE VII