

THE FOOD RELATIONS OF THE CARABIDÆ AND COCCINELLIDÆ.

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A group or association of animals or plants is like a single organism in the fact that it brings to bear upon the outer world only the surplus of forces remaining after all conflicts interior to itself have been adjusted. Whatever expenditure of energy is necessary to maintain the existing internal balance amounts to so much power locked up, and rendered unavailable for external use. In many groups this latent energy is so considerable and is liable to such fluctuations, that a knowledge of its amount and kinds, and of the laws governing its distribution, is extremely important to one interested in measuring or foreseeing the sum and character of the outward-tending activities of the class.

This seems especially true of the insect world. If the checks upon the multiplication of insects and upon their average length of life which are due to insects themselves were to be suddenly removed, there is much reason to suppose that the total external effect of the class would be very greatly intensified, at least for a time.

Whether our purpose be merely to understand the internal economy of insect life as a part of the general system of nature, or to apply such knowledge to a regulation of the depredations of insects upon plants and animals, it is equally necessary that we should know the character and extent of the conflicts which prevail within the class, and should understand how the various subordinate groups limit each other's numbers and activity, either indirectly by competition, or directly by destruction.

The following notes are a contribution to a more exact knowledge of this subject than has hitherto prevailed. The view of the functions of the two principal predaceous families of Coleoptera (Carabidæ and Coccinellidæ) which is common among

entomologists, is largely due to a hasty generalization, based upon insufficient data. Observations of the food of these beetles have hitherto been left almost wholly to chance, and have nowhere been systematically pursued—from which it has resulted that we know their habits only in the most conspicuous situations, and have not a fair idea of the general average of their food. Neither have observations of any kind been numerous enough to enable us to detect clearly differences of food habit in different species or genera of these families; but, with slight occasional exceptions, all Carabidæ and Coccinellidæ have been classed together as essentially carnivorous.

Besides insufficient observation, a tendency to reason too confidently from structure to function is responsible for many mistaken notions—a tendency particularly liable to mislead when applied to the habits of animals. It is frequently assumed that the most prominent and peculiar adaptive structures are necessarily indicative of the most important and customary habits, and that structures especially fitted for one function are thereby incapacitated for every other.

The first of these assumptions ignores the fact that many adaptive structures are acquired for the sake of the advantage derived, not in ordinary, but in extraordinary circumstances. The struggle for existence is one of greatly varying intensity, and the really decisive moments of the conflict are often only brief and occasional. The time spent in actual combat by very belligerent and very powerful animals, is doubtless but a small fraction of their whole lives; and yet by far the most prominent and important of the structural peculiarities which serve to distinguish them from their more peaceful allies, may be those which enable them to triumph in these occasional but critical instants. Likewise the pinch of starvation must commonly be felt only at rare intervals, but no structures will be more thoroughly elaborated or carefully preserved than those serving to give the animal the advantage during these brief periods, since the continued existence of the species depends on these no less than on those of constant use. From the prominent adaptive structures we may safely infer, as a general rule, what the animal will do in the stress of a life and death struggle, but not necessarily what are its ordinary practices.

The second of the above assumptions is also negatived, occa-

sionally, at least, by the principles of natural selection, especially as applied to the machinery of food prehension. Whatever departure from the primitive vegetarian habit of animals any group has acquired, was of course initiated to enable it to draw on other food resources than those previously open to it. But as animal food is usually less abundant and less generally distributed than vegetable, it would not, at first, be to the advantage of any that they should become exclusively dependent upon the former; their interests would be best served by such modifications of structure and habit as would enable them to draw upon one or the other store, according to circumstances. Acquiring some power to capture and masticate animal food, they would not wholly lose that of appropriating vegetable food also; and however well fitted their prehensile and digestive organs might become for the former function, we should expect that they would not altogether lose their fitness for the latter. It would be only as competition on this higher plane increased to the pressure point, that a few members of the differentiating group would be forced to the highest plane of complete dependence on animal food alone.

The first results of an attempt at a more exact and exhaustive investigation of this subject, were given by the writer in a brief paper published in Bulletin 3 of this series, in November, 1880.* In another paper by Mr. F. M. Webster in the same Bulletin,† a summary of previously recorded observations was given, together with many additional and original field notes. A few other items have since been published by others, but confined, as far as known to me, to chance observations on single insects.

The method here followed, as in the paper above mentioned, has been that of dissection. The alimentary canals of beetles taken in a great variety of situations, at various seasons and at different times of day, have been removed, placed in glycerine on microscope slides, and opened with small knives and mounted needles, so as to display the contents completely. These have then been studied with whatever power of the microscope was necessary, and mounted as microscope slides for permanent preservation and repeated examination. The amount of information

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which could thus be acquired by patient study, was often quite surprising. While it was of course rarely possible to distinguish species, or even genera, all the fragments could usually be classified with some fair degree of definiteness; and there was commonly no difficulty in making satisfactory estimates of the ratios of the different food elements present.

In some of the most important cases, the facts elicited were of the highest degree of exactness. Several collections of predaceous beetles were made in situations where some particular species of noxious insect was especially abundant, with a view to determining to what extent the latter was preyed upon by its supposed enemies. In such cases it was not difficult to tell with certainty, even from very minute fragments, whether the given insect had been eaten or not. Even where no solid structures were present, and the contents of the alimentary canal were entirely fluid, it was still usually possible to say whether these fluids had an animal or a vegetable origin. After many observations and some experiments, it was found that partially digested animal food in the stomach of a beetle was commonly bathed in a black juice, which, when examined under a high power of the microscope, was seen to contain nothing but a minutely divided flocculent matter, probably composed of irregular aggregations of fat droplets and other organic particles. This fluid was never found in connection with purely vegetable contents, but sometimes filled the stomach alone, and contained nothing to indicate its origin. In all the latter class of cases I have regarded it as proof that the food had been derived from animal sources, probably usually consisting of the juices of insects recently captured.

For the determinations of the fungi mentioned herein, I am indebted chiefly to Prof. T. J. Burrill, of the Industrial University at Champaign.

The insects dissected for this paper were partly obtained in the course of miscellaneous collecting, and partly secured for me especially for the purpose, by one of my entomological assistants, Mr. F. M. Webster, who kept careful notes of the situations in which the specimens were taken, the hour of the day when they were captured, and the objects upon which it seemed probable that they had lately fed. Examples of the latter were also frequently bottled with the specimens, for comparison. The special

collections from the orchard infested by canker-worms, and the corn-fields at Jacksonville and Normal overrun by chinch-bugs, were made by myself.

In the following discussion, each genus is taken up separately, and the details of its food are given both under general circumstances, as shown by specimens from miscellaneous situations, and also under the various peculiar conditions illustrated by the special collections, made for the purpose of exhibiting the food of these insects as related to particularly injurious species, and these are followed by a summary and discussion of the food of each family, taken as a unit. The tables exhibit, first, the food of the family under ordinary circumstances; second, under peculiar conditions; and, third, under all the circumstances, taken together.

FAMILY CARABIDÆ.

My notes upon the food of this family are derived from the dissection and study of one hundred and seventy-five specimens, representing thirty-eight species and twenty genera. Eighty-two specimens were collected in miscellaneous situations, twelve were taken in a field infested by cabbage-worms, ten in a corn-field overrun by chinch-bugs, and seventy-one in an orchard which was being destroyed by canker-worms. The first collection of eighty-two specimens from various situations represented thirty-two species, belonging to eighteen genera. They were obtained in different parts of the State, from DeKalb County in the north to Union in the south, and at all seasons of the year, from April to October; and doubtless represent fairly well the food of the family in Illinois during the entire year. The collections illustrating the food of the Carabidæ as related to the cabbage-worm were made in a field of young plants at Normal, Ill., in April, 1882, where the larvæ of *Agrotis annexa* were abundant and destructive. The collection showing the food of this family in the presence of the chinch-bug, consisted of ten specimens of a single species found in July, 1882, very abundant about the roots of corn in a field where the bases of the stalks were largely covered by young chinch-bugs. The third special collection consisted of seventy-one insects, representing nineteen species, obtained in May of two successive years (1881 and 1882) in an

orchard which had been infested for several years with the canker-worm to such an extent as to cause the total destruction of a large part of the trees.

GENUS CALOSOMA.

This genus is represented by three specimens of *C. scrutator*, collected in the orchard with the canker-worms, and by nine of *C. calidum*, which were variously distributed. The *C. scrutator* was found to have eaten only animal food, about two-thirds of which was recognizable as of insect origin. The remaining third was due to the occurrence of liquid animal food, or the fluid to which I have given this interpretation. In the stomach of one of the beetles the insect food consisted only of minute particles of a reddish brown crust which it was impossible to classify further. A single *C. calidum*, taken in May in Central Illinois, contained only liquid animal food. Seven specimens, taken in the orchard above-mentioned, had likewise fed upon animal food alone, forty per cent. recognizable as insects, and the remainder not otherwise determinable. As far as can be judged from the contents of the alimentary canal in these thirteen specimens, the species of this genus are strictly carnivorous, and have the habit either of sucking the juices of their prey, or of selecting only those parts most easily masticated, reducing these to indistinguishable fragments. Certainly there was not the slightest trace of vegetable food in any of these beetles.*

GENUS SCARITES.

Two specimens of *S. subterraneus*, taken in 1882, one at Normal and the other at Anna, in Southern Illinois, had eaten only animal food, one-half of which was unrecognizable, and the remainder insects. Four specimens of the same species, taken in the cabbage-field, have a precisely similar record.

These nineteen specimens, belonging to three species, were the only examples of *Carabidæ proper* whose food was studied, and all agreed in a strictly carnivorous character.

*Mr. F. M. Webster has seen a *C. calidum* eating a small grasshopper.

GENUS BRACHYNUS.

A single specimen of *Brachynus fumans*, caught in Central Illinois, in May, had taken only liquid animal food.

GENUS GALERITA.

Seventeen specimens of *Galerita janus*, four collected in various situations, and thirteen in the orchard in Tazewell County, had made a much more varied record. All of the group first mentioned had eaten insects, which amounted to eighty-eight per cent. of their food, nearly all caterpillars of undetermined species. The remaining twelve per cent. consisted of vegetable food eaten by two of the specimens, and was apparently derived chiefly from the seeds of grass. A larger ratio of animal food is noticed in the thirteen taken where canker-worms abounded. Here vegetation amounted to only six per cent., all of exogenous origin, as shown by the branching bundles of spiral cells in the vegetable fragments noticed, while the animal food amounted to ninety-four per cent. Insects stand at eighty-five per cent., seven per cent. being Diptera, one per cent. unrecognizable insect larvæ, and the whole of the remainder caterpillars. The last were nearly all easily determined as canker-worms, which amounted to a little over half the food. Seven individuals of the thirteen had eaten these worms. Five per cent. of the food (taken by three of the specimens) consisted of spiders, and four per cent. (taken by a single specimen) was animal food, not otherwise determinable. The remains of a caterpillar in the stomach of a single beetle were clearly distinguished as those of a noctuid larva (cutworm).

If from the ratios of animal food taken by the examples from the orchard we subtract the ratio of canker-worms (fifty-two per cent.) the remainder is just seven times the ratio of vegetation eaten. Recalling the percentages of animal and vegetable food taken by the four specimens first mentioned, we find that here also the former is almost exactly seven times the latter. This shows beyond question that the canker-worms eaten were *in addition* to the ordinary ratio of animal food taken by this species under the usual conditions.

GENUS LOXOPEZA.

Three specimens of this genus were studied, all belonging to the species *L. atriventris*, collected in July and September in Northern and Central Illinois. One of these had eaten immense numbers of minute, oval, binucleate cells, determined by Prof. Burrill as spores of *Sphaeronemei*, probably *Phoma*, a fungus which forms small black specks upon dead wood, stems of weeds, etc. A second specimen had eaten some undetermined insect, and about equal quantities of three elements, namely: the above spores of *Phoma* and pollen and anthers of grass,—doubtless blue grass, upon which the insect was taken. A few spores of *Helminthosporium* were likewise noticed. The crop of a third specimen, taken at Normal, was distended with an oily liquid, but contained nothing else except a few spores of *Helminthosporium*. This specimen had probably been sucking the juices of some insect. The ratios of animal and vegetable food, as nearly as I could estimate them, were as forty-four to fifty-six. A specimen of this species, captured in the orchard, had not recently taken food.

GENUS CALATHUS.

Six examples of *C. gregarius*, three from DeKalb County and three from the orchard, are the only representatives of this genus. One-third of the food of those first mentioned consisted of caterpillars, a second third of other insect larvæ, and the remainder of the pollen of grass. The food of the second group was extremely similar, a third consisting, as before, of vegetation, another third of canker-worms, and the remainder of insect fragments not further determinable.

GENUS PLATYNUS.

The stomach of a single *P. decorus*, taken in the orchard, contained only liquid animal food. Two examples of *P. limbatus*, both from Southern Illinois, in April, had derived about four-fifths of their food from the vegetable kingdom, partly seeds of grass and partly the parenchyma of exogenous plants. The remainder consisted entirely of Aphides (plant-lice). These specimens were doubtless too few to give a correct idea of the average food of the genus as a whole.

GENUS EVARTHUS.

Five specimens of *E. colossus*, taken at various dates and places, had derived about one-tenth of their food from endogens, and the remainder wholly from insects. Twenty per cent., eaten by one of the beetles, was recognized as caterpillars. Scarabæidæ are credited with another twenty per cent., and undetermined larvæ of Coleoptera with about an equal ratio. Minute quantities of fungi were noticed in the stomachs of two of these beetles, and traces of undetermined Algæ in one.

Two examples of *E. sodalis*, taken in the Tazewell County orchard, had consumed only insects, all canker-worms, except traces of an ant and a single gnat.

The insect ratio of the genus as represented by these seven specimens, stands at ninety-three per cent.

GENUS PTEROSTICHUS.

Thirteen specimens were dissected, representing *P. permundus*, *P. sayi*, and *P. lucublandus*.

The number of each species is not sufficient to give distinctive food characters, and the genus may therefore best be treated as a whole. Seven of the specimens, taken in miscellaneous situations in Central Illinois in April, May, and September, had found about one-fourth of their food in the vegetable kingdom, about one-third of which consisted of undetermined fungi, and the remainder chiefly of exogenous plants. A few spores of Helminthosporium, probably accidental, were noticed in the stomach of a single beetle. Forty-three per cent. of the food consisted of insects, among which Hymenoptera only were recognized. A single mite occurred in one of the beetles. Three specimens taken in the orchard infested by canker-worms, had eaten endogenous vegetation, to the amount of about one-fifth of their food. Caterpillars made eleven per cent., and undetermined insects two per cent., the remaining ratio being accounted for by the presence of liquid animal food. Two-thirds of the contents of three specimens taken among the cabbages, consisted of animal matter, half of which was clearly recognized as the larvæ of *Agrotis annexa* infesting the field. The remaining third, composing the

entire food of one of the beetles, consisted wholly of fragments of grass.*

GENUS AMARA.

Six specimens of this genus were dissected, three of *A. carinata*, one of *A. angustata*, and two of *A. impuncticollis*. Three specimens of *A. carinata*, taken in Southern Illinois in April, 1882, had eaten only vegetation, partly derived from graminaceous plants, and partly consisting of seeds and exogenous tissues. About one-fourth of the food was recognizable as fungi, chiefly of the genus *Peronospora*. Ninety per cent. of that of a single *A. angustata*, taken in June, consisted of mites, the remainder being fragments of grass. An *A. impuncticollis*, taken in the orchard with the canker-worms, had eaten only vegetable food, chiefly undetermined, but with traces of fungi. Another of the same species from the cabbage field, had derived its food about equally from plant and animal sources, that from the former consisting chiefly of grass.

GENUS DICÆLUS.

Three examples of *Dicælus elongatus* had taken only animal food, as indicated by the fluid contents of the stomachs. One of these was found in the orchard, and the other in Central Illinois.

GENUS CHLÆNIUS.

This genus is represented by twenty-three individuals, the next to the largest number studied of any genus of Carabidæ. Six examples from Southern Illinois, collected from April to September, belong to the species *C. diffinis*, *C. nemoralis*, and *C. tomentosus*. The animal food of these was about three times the vegetable. Two-thirds consisted of insects, of which caterpillars alone were determinable; and earth-worms eaten by one of the beetles made about eight per cent. More than half the vegetable food consisted of fungi, which included fourteen per cent. of some fleshy fungus, apparently *Coprinus*, together with spores of *Dematiei*. Fragments of exogenous plants were recognized in one of the beetles. A single *C. diffinis*, taken among the cab-

*A specimen of *P. lucublandus* was seen by Mr. F. M. Webster making a meal from a dead *P. sayi*.

bage-worms, had eaten only insects, chiefly a caterpillar, and a larva of a beetle. A mere trace of endogenous vegetation was also detected. Of sixteen specimens collected among the canker-worms, three were *C. erythropus*, and thirteen *C. diffinis*. Cut-worms made about one-third of the food of the first, and earth-worms the remaining two-thirds. The latter were easily distinguishable by the peculiar spines mixed with dirt in the stomachs of the beetles. About ninety per cent. of the food of the other species was of animal origin, and about half the vegetable food was fungi. Insects made seventy-two per cent., nearly half caterpillars, of which the greater part (thirty-one per cent.) was canker-worms. Fragments of a fly were observed in one of the beetles, and another had eaten one of the *Telephoridæ*. Mites and myriapods (*Geophilus*) had also been devoured by one.

GENUS AGONODERUS.

Fifteen specimens of *Agonoderus* were studied, ten of which were those already referred to as representing the food relations of these beetles to the chinch-bug. Fragments of that insect amounted to about one-fifth the food of all, and were found in four of the beetles; and plant-lice, taken by half that number, amounted to about eight per cent. A single ant, *Lasius flavus*, eaten by one, was rated at five per cent.; and other insects brought the general average of the class up to thirty-five per cent. Vegetation made just half the food, all fragments of the higher plants except one per cent. each of *Helminthosporium* and *Peronospora*. A single *Agonoderus*, taken among the cabbages, had eaten only undeterminable animal food. Four specimens from various situations had made a similar record, differing only by the presence of a few mites in the stomach of one of the beetles. Eleven per cent. of fungi, taken by the group last mentioned, was derived from *Ramularia* and *Coleosporium*. The circumstances of capture, together with the contents of the stomach of one of these beetles, indicated that it had made its meal chiefly from the seeds of June grass, but the remainder of the vegetable food could not be more definitely classified.

GENUS ANISODACTYLUS.

This large and abundant genus is represented by thirty-one specimens, belonging to six species. Five specimens of *A. rusticus* were examined, captured in McLean and DeKalb Counties in May, June, and July. Two of these had taken only liquid animal food, but the remaining three had eaten no animal matter at all. Among the fungi found, Cladosporium and Peronospora were recognized, and fragments of Hepaticæ were noted in two of the beetles. Two specimens of *A. harrisi*, taken in Union County in April, 1882, had eaten only vegetation, all seeds of grass and of other plants. A single *A. discoideus* from McLean County in June, contained nothing but liquid food. Seven examples of *A. baltimorensis*, widely distributed in time and place, had derived only about fourteen per cent. of their food from the animal kingdom, all taken by one of the beetles, whose stomach contained only chyme. About half of the eighty-six per cent. of vegetation, composing the entire food of the remaining six specimens, was demonstrably obtained from the seeds of June grass, upon which several of the insects were taken. Two examples of *A. sericeus* from Northern Illinois had made about three-fourths of their food of grass, and the remainder of unrecognizable insects. In the stomachs of two specimens of *A. opaculus*, fragments of seeds and other vegetation were the only objects found.

Taking together the nineteen specimens of this genus above mentioned, collected in various places, we find that animal food made about one-fourth of the total, and that the vegetation as far as recognized was chiefly derived from June grass and other graminaceous plants.

The record of ten specimens taken from the canker-worm orchard, is not especially different from that of the foregoing group. Only one of these had eaten animal matter at all, ninety per cent. of the food of this consisting of undetermined Diptera. Here, again, the recognizable vegetation was chiefly graminaceous, only ten per cent. being clearly derived from exogenous plants. Two specimens from the cabbage field afford no occasion for special remark. The stomach of one was distended with liquid animal food; that of the other contained vegetation only.

GENUS AMPHASIA.

Four examples of *A. interstitialis* indicated that this species is almost strictly vegetarian, only three per cent. of the food consisting of insects. Of the remaining ninety-seven per cent., little can be said except that it was certainly of vegetable origin.

GENUS BRADYCELLUS.

A single specimen of *B. dichrous* had eaten only insects, which could not be further classified.*

GENUS HARPALUS.

Nineteen specimens of Harpalus were studied, belonging to the three species *caliginosus*, *pennsylvanicus*, and *herbivagus*. Two individuals belonging to the first of these species, from Normal and Towanda in August and September, had taken about one-tenth of their food from insects (caterpillars and Diptera). Twenty per cent. of unrecognizable animal food and five per cent. of mites bring the general average up to thirty-five per cent. The sixty-five per cent. of vegetation eaten consisted chiefly of tissues of grass. A little pollen of Compositæ, and other exogenous structures were likewise recognized. Three per cent. was fungi, all spores of Helminthosporium. Seven specimens of *H. pennsylvanicus*, caught in Northern, Central, and Southern Illinois, in April, August, and September, had taken about one per cent. of their food from the animal kingdom. This included an ant eaten by one of the beetles, and a few mites taken by another. About half the vegetable food was not further recognizable. Twenty-nine per cent. was the pollen of rag-weed, taken by two beetles captured upon that plant, and fourteen per cent. was derived from June grass. Fungi made eight per cent. of the food of these beetles, a little of it Helminthosporium, but chiefly Peronospora. Three examples of *H. herbivagus*, taken in Northern Illinois, had eaten only vegetation, about one-third of it graminaceous, and another third fungi. Only seven per cent. of the food of the above twelve specimens of this genus, taken from

*Mr. Webster reports a specimen of *B. rupestris* taken in 1881 in the act of devouring an earth-worm.

ordinary situations, consisted of animal food, of which a little less than half was insects. Fungi made thirteen per cent., and the remaining vegetable food was about equally divided between grasses and exogenous plants. Three specimens of *H. caliginosus* and *H. pennsylvanicus*, taken among the canker-worms, had derived one-third of their food from those caterpillars, while the other two-thirds consisted of vegetation, sixteen per cent. being Peronospora, and the remainder chiefly seeds and exogenous tissues. Four specimens of *H. herbivagus*, collected in the cabbage field, in April, had eaten none of the cabbage-worms, and only ten per cent. of insects (Diptera). The remainder of the food consisted apparently of fragments of seeds, as indicated by the contents of the cells of the fragments and by other microscopic characters. A piece of the epidermis of grass was noticed in one of the beetles. Taking the genus Harpalus as a whole, as far as these nineteen specimens can be supposed to indicate its food, we find that only about one-eighth of it consisted of animal substances. Insects stand at nine per cent., two-thirds of them caterpillars,—ants and Diptera making up the balance. Among the items on the vegetable side of the account, we find fungi and pollen of Compositæ each eleven per cent. and seeds and other tissues of grasses, fourteen per cent.

GENUS PATROBUS.

Two specimens of *P. longicornis*, one from Central and the other from Southern Illinois, had eaten nearly twice as much vegetation as animal food. The latter consisted chiefly of caterpillars, and included in fact nothing else but traces of plant-lice, eaten by one of the two. A little of the vegetation was derived from grass, but the source of the remainder could not be satisfactorily traced.

THE FAMILY AS A UNIT.

We have now to treat the various collections of Carabidæ upon which this paper is based, as distinct and unbroken groups, without reference to the genera of which they are composed. The eighty-three specimens of all the species obtained in miscellaneous situations, are found to have derived forty-two per cent. of their food from the animal kingdom, while the seventy specimens

captured in the orchard so often mentioned took seventy-seven per cent. of their food from the same sources. The individuals from the cabbage field, however, show no such excess of animal food as those just mentioned, the ratios standing for them at forty-one per cent. If we seek to account for this striking surplus shown by the second group, we shall find, in the first place, a difference of more than sixteen per cent. between the ratios of insects eaten by the first and second groups respectively—a fact clearly due to the presence of canker-worms where the second group was collected. This species was eaten by sixteen of the seventy beetles, and composed about one-fifth of the contents of all the alimentary canals. This accounts, however, for only about half the difference noted, the remainder appearing in the larger ratios of the other insects, of mollusks, of earth-worms, and of undetermined animal food.

This indicates either that other forms of animal life than the canker-worms were superabundant in the orchard, or else that the miscellaneous collections do not correctly represent the ordinary food of the Carabidæ. The truth probably lies between the two. The extraordinary wetness of the season, together with the amount of rubbish on the ground in the orchard, gave these beetles an unusual opportunity to capture slugs and earth-worms, and afforded excellent harborage for all sorts of insects. On the other hand, many of the beetles from other situations were preserved especially for dissection because the circumstances of their capture made it seem probable that they were feeding upon vegetation.

These tables indicate one interesting and important fact with regard to the preferences of this family, namely, that where an extraordinary abundance of any kind of animal food appeared, with a consequent increase in the percentage of that kind appropriated by the beetles, this increase was compensated, not by a decrease in the other animal elements, but in the ratios of vegetation only—a fact which clearly shows that the preferences of the Carabidæ are for animal food. It should be noticed, however, that this argument does not apply to all the genera, as is seen, for example, by recalling the record of *Anisodactylus*. The ten specimens of this genus taken in the orchard had eaten much more vegetation than the nineteen from various other places.

The combination of these various tables into the final one given will tend to correct the deficiencies of the separate exhibits, and the averages of that table will consequently be found to represent more closely the general food of the family than either of the others.

Continuing the comparison of the three separate tables, we find that the beetles represented by the first had taken insects to the amount of twenty-six per cent.; that those from the orchard had about doubled this ratio; while those from the cabbage field fell a little short of it. This last fact is probably related to the time of the year when these beetles were taken—the middle of April in a very late spring, when insect life in general was but just beginning to stir abroad. The ratios of Diptera, Coleoptera, and Hemiptera, were but trivial in all these groups, and not worth separate mention. The extraordinary difficulty of determining the elements of the vegetable food from the minute fragments found in the stomachs of these beetles, makes it impossible to enter into much detail with respect to this. The miscellaneous collections and those from the cabbage field had found a little over half their food in the structures of plants, while those from the orchard had obtained from this source somewhat less than a quarter. Pollen of exogenous plants, which will be found to form so large a ratio of the food of the family next to be considered, appeared here only in three of the specimens, and amounted to but three per cent. of the entire food of the first group. These beetles fed much more largely on graminaceous plants, the recognizable tissues of which amounted to about seventeen per cent. in the first group, and eight in each of the special collections. Fungi were reckoned at about one-tenth of the food of the beetles included in the first collection, and only two per cent. of those from the orchard. The spores of the omnipresent *Helminthosporium* make the most important contribution to this element of the food, but a number of other genera were recognized.

A few words will suffice for the final table, summarizing the data relating to all the collections, from whatever source derived. This table presents the ratios from one hundred and seventy-five specimens, and as already remarked, a little over half the food of all consisted of animal matter, about one-third being insects,

while mollusks, earth-worms, myriapods and Arachnida make up the remainder.

All orders of insects are represented on the list, with the exception of Orthoptera and Neuroptera. The ratios of none of these are of any special importance, except that of the Lepidoptera, which stands at fifteen per cent. Hymenoptera and Diptera are each one per cent., and Coleoptera and Hemiptera each two. Among the Coleoptera, only Scarabæidæ and Telephoridæ were recognized; among the Hymenoptera only a single ant; and among the Hemiptera, plant-lice and chinch-bugs only. About half the vegetable food could be distinguished as exogenous or endogenous, the remainder being of too indefinite a character to be assigned to either class. As far as known, the endogenous food was more than twice as abundant as the exogenous, and consisted almost wholly of grass or grass-like plants. The fungi, which make somewhat more than a fourth of the food, require no further special mention.

If, discarding the ratios given above, we look only to the number of specimens in which the various food elements are detected, we reach similar results. One hundred and seventeen individuals of the one hundred and seventy-five represented by this final table had eaten animal food, and ninety-seven had taken vegetation. Insects were recognized in eighty-two, Lepidoptera in thirty-one (about one-half of which had eaten canker-worms), Diptera and Coleoptera in nine and four respectively, and Hemiptera in seven. Earth-worms were found in five, myriapods (*Geophilus*) in but one, and Arachnida (mites and spiders) in nine. Grass-like plants were taken by thirty-six, and fungi by twenty-nine.

Scanning the totals for each genus on this final table, a few results are noted which are worthy of special remark. First, we observe that at least two very abundant genera, represented by specimens enough to give us a fair probability that the average food is correctly exhibited, can hardly be classed as carnivorous insects at all, namely, *Harpalus*, with its nineteen specimens and twelve per cent. of animal food, and *Anisodactylus*, with its thirty-one specimens and twenty-one per cent. of the same. *Amara* and *Amphasia* should probably be placed in the same category, six specimens of the first and five of the second having taken but twenty-three per cent. and seven per cent., respect-

ively, of food of animal origin. The excessively abundant *Agonoderus* ranks but little higher as a carnivorous insect, fifteen examples having derived only about one-third of their food from animal sources. On the other hand, twenty-three specimens of *Chlænium*, and seventeen of *Galerita* had taken about nine-tenths of their food from insects, mites, myriapods and earth-worms. Thirteen specimens of *Pterostichus* had obtained three-fourths of theirs from similar sources, while *Evarthrus* and *Calathus*, represented by seven and six specimens respectively, had averaged ninety-three per cent. and sixty-seven per cent.

The fact has already been alluded to that the Carabidæ proper had eaten only animal food, and that nearly all this was of a fluid character.

Second, we find the Carabidæ dividing into at least three tolerably distinct groups as respects their food: first, those which seem usually to seize their prey and suck its juices, and take vegetation rarely, if at all; second, those which take a much larger ratio of animal food than of vegetable, but masticate and swallow it, as a rule, including indigestible fragments; and third, those whose habit is essentially vegetarian, but which still take solid animal food in diminished ratios. A fourth group, consisting of *Lebia* and its allies, is perhaps obscurely indicated by the facts relating to the three specimens of *Loxopeza atriventris* studied. This will probably be found to feed largely upon pollen and fungus spores, after the manner of the Coccinellidæ; and the fossorial Carabidæ will, perhaps, constitute a fifth.

If we look now to the structures of these beetles for some explanation of their differences of habit, we shall find corresponding variations in the form and structure of the mandibles. Where the mandibles are long and curved, and are destitute of basal molar processes, but are provided at or near the middle of the cutting edge with processes relatively long and sharp, the beetle seems to feed substantially upon soft or liquid animal food. If they are of medium length, somewhat slender, broad at base and tapering distally, with the tip acute, and provided with basal processes which are not especially prominent or sharp, the food is chiefly animal, but solid structures are masticated and swallowed, and some vegetation appears in the alimentary canal; while, finally, if they are short and quadrate, blunt at the tips, and provided either with strong

basal processes or broad opposed surfaces, vegetable food is found to predominate. *Calosoma* is an example of the first of these classes, *Chlænium* of the second, and *Anisodactylus* of the third. The seeming exceptions to this generalization shown by the tables at the close of the paper, are found among those genera of which too few specimens have been studied to warrant general conclusions respecting their food.

FAMILY COCCINELLIDÆ.

This family shares with the preceding the credit of limiting the multiplication of other insects, but was shown in the Bulletin of the Laboratory previously mentioned, apparently to depend largely while in the adult stage upon fungi and other vegetable food. The notes in the paper mentioned referred, however, to so small a number of specimens as to make this conclusion of doubtful value. Numerous dissections of Coccinellidæ made since that time have afforded the material for a much more comprehensive and thorough treatment of the subject, and the results of a careful study of thirty-nine slides are herewith given. The Aphis-eating habit of the Coccinellidæ is a fact of such easy observation, and is so thoroughly well known, that I have not thought it worth while to investigate especially the food of beetles of this family taken among plant-lice.

The collections from which the present notes are derived, are from a variety of miscellaneous situations, and also from a corn-field mentioned in the notes on the food of the preceding family, in which chinch-bugs were superabundant, the purpose of the latter collection being to determine the food relations of the Coccinellidæ to those insects. It so happened that the same field was infested by the corn Aphis in great numbers, and the specimens obtained therein consequently illustrate to some extent the food of the lady-bugs in the presence of plant-lice. It was in this last situation only that larvæ were collected, and the facts here given consequently relate almost wholly to the adult beetles.

GENUS HIPPODAMIA.

Eleven specimens of *H. maculata*, taken in Northern, Central, and Southern Illinois at various seasons of the year, from April to

September, give an average of forty-six per cent. of animal food, all insects excepting a few mites eaten by three of the beetles, and amounting to only one per cent. of the food. The insect ratio, as far as recognized, with the exception of a single *Podura*, consisted wholly of plant-lice, which amounted to thirty-five per cent., while the fifty-four per cent. of vegetable food contained only pollen of plants and spores of lichens and fungi, the pollen and spores occurring in about equal quantities. The former was chiefly from flowers of grass and composite plants, about seven per cent. of the first and fifteen per cent. of the second. One per cent. of the pollen of *Polygonum*, and a trace of the pollen of pine, both eaten by a single beetle, are the only other items under this head. Lichen spores, including *Physcia*, were reckoned at two per cent., and those of fungi at twenty-five per cent. At least two-thirds of the latter, eaten by nearly half the beetles, consisted of spores of *Helminthosporium*.

Three specimens of this species, taken in the corn-field at Jacksonville, had eaten much smaller ratios of animal food, which amounted to only thirteen per cent., all insects. Traces of plant-lice were recognized, but no structures of chinch-bugs occurred. All but five per cent. of the vegetable food was derived from spores of fungi, very largely *Cladosporium*. *Helminthosporium* amounted to nine per cent. *Macrosporium* and *Septoria* were also found. Three per cent. of the spores of *Physcia* and other lichens, and two per cent. of the pollen of rag-weed and other *Compositæ*, complete the record.

Four examples of *H. convergens*, all taken at Normal in August and September, had eaten about the same amount of animal food as the preceding species (forty per cent.), but differed in the distribution of it by the fact that one of the specimens had eaten a myriapod (*Geophilus*), and that a caterpillar had been taken by another. Insects proper amounted to but twenty-five per cent., over half plant-lice. The vegetable food of this species stands at fifty-six per cent., as compared with fifty-four of the preceding, and the ratios under this head are very similar to those just given for the other species. Pollen of *Compositæ* (dandelion) makes thirteen per cent. that of grass makes five per cent., spores of lichens two, and those of fungi thirty-three per cent. As in *H. maculata*, *Helminthosporium* was by far the most important

fungus element. The other genera recognized were Septoria, Ustilago, Macrosporium, Coleosporium, Peronospora, Menispora, and some spores of Sphæronemei and Myxogastres.

Five adults, taken at Jacksonville, were found to have made about one-third of their food of insects, equally divided between plant-lice and chinch-bugs, each eaten by one of the beetles. The vegetation consisted, as usual, of pollen of Compositæ (eleven per cent.), spores of lichens (two per cent.), and of fungi (seventy-one per cent.). The list of the last includes Septoria, Ustilago, Helminthosporium, Macrosporium, Cladosporium, and Peronospora.

Two larvæ of this species, taken at the same place and time, differed but little in food, to my surprise, from the adults just mentioned. Chinch-bugs, plant-lice, and caterpillars, in about equal ratios, with traces of unrecognizable insects, amount to twenty-three per cent. Pollen of Compositæ stands at five per cent., lichen spores at seven, and spores of fungi at sixty-five, including the same genera as those just mentioned, except Peronospora and Septoria.

H. glacialis was represented by four specimens, taken in the corn-field. The differences between their food and that of *H. convergens* were purely trivial. Insects amount to thirty per cent., all chinch-bugs and plant-lice, twelve per cent. of the former and eighteen of the latter. The seventy per cent. of vegetable food is divided about as before, between pollen of Compositæ, seven per cent., and spores of fungi fifty-one per cent. Lichen spores were taken more freely, however, and were estimated at twelve per cent., eaten by all the beetles. The fungi were mostly Cladosporium (forty-three per cent.), but Septoria, Uredo, Helminthosporium and Peronospora likewise occur.

GENUS COCCINELLA.

Six specimens of this genus were studied, three of *C. 9-notata*, and three of *C. 5-notata*. All were from Central Illinois except one, which was from Jacksonville. Excluding the last, the ratio of animal food eaten by these specimens was not far from two-thirds of the total, all plant-lice. Only a trace of pollen of Compositæ was noticed in one of the insects. Fungus spores amounted to thirty-two per cent. (about half Helminthosporium and Ustilago),

and lichen spores to four per cent. The Jacksonville specimen had eaten only fungi.

GENUS CYCLONEDA.

In the corn-field with the chinch-bugs, three specimens of *C. sanguinea* were collected, which had eaten plant-lice, pollen of Compositæ, lichen spores and spores of fungi. The first made about one-third of their food, the pollen grains were estimated at nearly half, and lichen spores at three per cent. The eighteen per cent. of fungi were of the usual character.

THE FAMILY AS A UNIT.

A summary and comparison of the food of these two groups, taken singly without reference to their genera, develops some interesting and unexpected facts. Although the corn-field in which the second collection was made was teeming with insects of the kinds especially tempting to the Coccinellidæ, and although these beetles themselves were there in truly surprising numbers, it is not easy to believe, considering the tables upon which this discussion is based, that the Coccinellidæ were attracted to the field by the abundance of insects available for their food. The beetles of the first group are seen to have eaten nearly twice as many insects as those from the field of corn, while the fungi eaten were as thirty-six to fifty-six respectively. Only eighteen specimens were dissected, out of the large number collected in the corn-field, but the contents of their stomachs were of so uniform a character that there was every reason to suppose that they illustrated correctly the food of the family at that time and place. It would therefore seem possible that these beetles were attracted rather by the stores of fungi in the field, than by the chinch-bugs and Aphides. The condition of the leaves and stalks of the corn, drained and deadened by insect depredations, was such as to afford an excellent nidus for the development of those fungi which spring up every where spontaneously upon dead and decaying vegetation, and these were in fact extremely abundant. An alternative explanation is perhaps more probable. The condition of the field gave abundant evidence that the plant-lice had been very much more numerous some time before; and it is possible that, as a consequence of this decrease of food, and the increase of

the Coccinellidæ themselves, the latter had reached an excessive number, for which the supply of plant-lice was really insufficient, and that for this reason they had resorted to fungi.

The chinch-bugs taken by the specimens of the second group amounted to only eight per cent. of their entire food, and plant-lice to fourteen per cent.,—less than half those taken by the other specimens, which stand at thirty-six per cent. The pollen eaten by each group was thirteen per cent.,—the same in both. If we combine the two collections, and treat the thirty-nine specimens of both as a whole, we find that insect food is about a third of the entire amount, and that the other animal elements are only trivial. The function of the beetles of this family of limiting the multiplication of plant-lice is expressed by the fact that these insects compose a fourth of the food of this entire collection. The pollen of grasses and Compositæ make fourteen per cent., the spores of lichens four per cent., and those of fungi nearly half the whole (forty-five per cent.). The list of genera, as far as recognized, and the relative importance of these, may be found by reference to the tables at the end of this paper.

SUFFICIENCY OF DATA.

The food of the Coccinellidæ seems to be, on the whole, remarkably simple and uniform, consisting almost wholly of spores of the lower cryptogams, pollen grains, and plant-lice, and varying but little from one genus to another. This similarity is likewise reflected in the mouth parts, which agree as closely in form and structure as do the ratios of the food. I have consequently little doubt that the data derived from the thirty-nine specimens here discussed, will be found sufficient for a correct general idea of the food of the family under ordinary circumstances.

With respect to the Carabidæ, we have other proof. In the preliminary paper in Bulletin 3 already referred to, based on an examination of only twenty-eight specimens belonging to seventeen species, the conclusion was announced that about one-half of the food of this family consisted of vegetation, and one-third of insects; and the vegetation was thought to be about equally divided between cryptogams, grasses and exogens. If these figures or those of the present paper were far wrong, the probabilities would be very slight indeed that the two estimates would agree,

especially as no comparison whatever was made of the two sets of data until the tables were completed in their present form. When, therefore, we find that the one hundred and seventy-five specimens of the present paper, belonging to thirty-eight species, were estimated to have taken fifty-seven per cent. of animal food and thirty-six of insects, and that the ratios of cryptogams, graminaceous plants and exogens are respectively five, eleven, and five, we must conclude that these figures are a fair average of the ordinary food of the family.

RELATIONS TO BIRDS.

The foregoing pages have set forth the relations of the Carabidæ and the Coccinellidæ to the species upon which they feed, and a few general statements will now be proper concerning the animals which prey upon them in turn. Predaceous ground-beetles are peculiarly exposed to birds which commonly seek their food upon the ground, and we need not be surprised to find that they enter largely into the food of such species as the thrushes and the bluebird. Carabidæ were found to furnish about five or six per cent. of the food of four hundred and twenty-three specimens of these birds, as stated in a paper on that subject in the third Bulletin of this series, but Coccinellidæ did not occur at all. Indeed, in the food of more than four hundred other birds, of various families, Coccinellidæ were found only in *Regulus*, where a single species was reckoned at one per cent. of the food.

The great differences in the food of the Carabidæ, disclosed by this paper, give considerable importance to the question of the kinds of these beetles most freely eaten by birds, and the following list of species and genera recognized in the food of the collection of thrushes and bluebirds above mentioned is given as an answer.

It will be seen that there is a very wide difference between the number of Carabidæ proper taken by these birds, and the number of Harpalidæ, representatives of the former group occurring in only six specimens, and of the latter in one hundred and sixteen. On the other hand, fifty-nine of the birds had taken Harpalids which may be fairly classed with the second group established in this paper, and fifty-seven had taken those belonging to the third group, or phytophagous Carabidæ. The genera most preyed

upon are Harpalus, taken by twenty-eight of the birds, Anisodactylus by eighteen, Agonoderus by fourteen, Cratacanthus by thirteen, Pterostichus by twelve, and Evarthrus by eleven; numbers which represent fairly well the relative abundance of individuals, taking the entire season through. We note, however, a remarkable deficiency of the highly colored genera,—such as Galerita, Brachynus, Lebia, Platynus, Chlænius, etc., which are either absent, or found but rarely in these birds' food. Evidently these more showy beetles are protected by some more effective means than obscurity of color. In the following list, the figure preceding the name of each species of bird denotes the number of specimens in which the insect mentioned was found:

LIST OF GENERA AND SPECIES OF CICINDELIDÆ AND CARABIDÆ EATEN BY 423 OF THE THRUSHES AND THE BLUEBIRD.

1. Cicindela lecontei: 1 Mimus carolinensis.
2. Carabus palustris: 1 Sialia sialis.
3. Scarites, sp.: 1 Harporhyncus rufus.
4. Dischyrius globulosus: 1 Turdus pallasi.
5. Aspidoglossa subangulata: 2 Mimus carolinensis.
6. Clivina bipustulata: 1 Harporhyncus rufus.
7. Platynus, sp.: 1 Mimus carolinensis, 1 Harporhyncus rufus, 1 Sialia sialis.
8. Evarthrus, sp.: 1 Turdus mustelinus, 1 T. migratorius, 2 Mimus carolinensis, 5 Sialia sialis.
9. E. colossus: 1 Turdus pallasi, 1 Harporhyncus rufus.
10. Pterostichus sp.: 1 Turdus mustelinus, 1 T. pallasi, 1 T. migratorius, 1 Harporhyncus rufus, 5 Sialia sialis.
11. P. lucublandus: 1 Turdus mustelinus, 1 Sialia sialis.
12. P. sayi: 1 Mimus carolinensis.
13. Amara, sp.: 1 Turdus pallasi, 1 T. swainsoni, 1 T. migratorius, 2 Sialia sialis.
14. Brachylobus lithophilus: 3 Turdus migratorius.
15. Chlænius, sp.: 1 Turdus migratorius, 1 Sialia sialis.
16. C. tomentosus: 1 Sialia sialis.
17. Lachnocrepis parallelus: 1 Turdus migratorius.
18. Geopinus incrassatus: 1 Turdus migratorius.
19. Cratacanthus dubius: 1 Turdus mustelinus, 3 T. migratorius, 2 Mimus carolinensis, 2 Harporhyncus rufus, 5 Sialia sialis.

20. *Agonoderus*, sp.: 2 *Turdus migratorius*, 1 *Mimus carolinensis*, 1 *Harporhyncus rufus*, 1 *Sialia sialis*.
21. *A. pallipes*: 2 *Turdus migratorius*, 1 *Mimus carolinensis*, 1 *Harporhyncus rufus*, 2 *Sialia sialis*.
22. *A. partarius*: 1 *Turdus migratorius*.
23. *Anisodactylus*, sp.: 1 *Turdus mustelinus*, 1 *T. swainsoni*, 2 *T. migratorius*, 2 *Harporhyncus rufus*, 6 *Sialia sialis*.
24. *A. rusticus*: 1 *Sialia sialis*.
25. *A. discoideus*: 1 *Turdus pallasi*.
26. *A. baltimorensis*: 2 *Turdus migratorius*, 1 *Mimus carolinensis*, 1 *Sialia sialis*.
27. *Xestonotus lugubris*: 1 *Turdus mustelinus*, 1 *Sialia sialis*.
28. *Harpalus*, sp.: 1 *Turdus mustelinus*, 7 *T. migratorius*, 4 *Mimus carolinensis*, 8 *Harporhyncus rufus*, 6 *Sialia sialis*.
29. *H. herbivagus*: 1 *Turdus migratorius*.
30. *H. pennsylvanicus*: 1 *Mimus carolinensis*.
31. *Stenolophus*, sp.: 2 *Turdus pallasi*.

In the following tables, the elements of the food, arranged in systematic order, are placed at the left of each page, while a vertical column of the table is assigned to each genus of beetle. The upper figure of each couple indicates the number of specimens in which the given element was found, while the lower figures (decimal) show the ratio of the element to the entire food of all the examples of the genus. The dagger has been used to indicate a trace too small to figure in the percentages, usually less than one-half per cent., and an asterisk denotes that the element against which it is placed was present in the food, but that the ratio was not estimated.

CARABIDÆ.—MISCELLANEOUS COLLECTIONS.

	Calosoma.	Scarites.	Brachynus.	Galerita.	Lebia.	Calathus.	Platynus.	Evarthrus.	Pterostichus.	Amara.	Dicelus.	Chlaenius.	Cratacanthus.	Agonoderus.	Anisodactylus.	Amphasia.	Bradycellus.	Harpalus.	Patrobis.	Summary.
No. of Specimens.....	1	2	1	4	3	3	2	5	7	4	2	6	1	4	19	4	1	12	2	83
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.																			
	1	2	1	4	2	2	1	5	6	1	2	5	1	3	1	1	4	1	4	1
ANIMAL FOOD.....	1.00	1.00	1.00	.88	.44	.65	.17	.90	.73	.22	1.00	.75	...	.01	.24	.03	1.00	.07	.33	.42
I. INSECTA.....		.50		.88	.11	.65	.17	.90	.43			.67			.03	.03	1.00	.03	.33	.26
Larvæ.....						.32		.10				.08								.02
1. Hymenoptera.....									1		.13							.01		.01
Formicidæ.....																		.01		+
2. Lepidoptera (larvæ).....				.63		.33		.20				.17						.02	.30	.08
3. Diptera.....																			+	+
4. Coleoptera.....								2			.39									.02
Larvæ.....								1			.19									.01
Scarabæidæ.....								1			.20									.01
5. Hemiptera (Aphides).....								1			.17								.03	.01
II. ARACHNIDA (Mites).....									1	1	.22			1	.01			2		.01
III. VERMES (Lumbricus).....												1	.08							.01
VEGETABLE FOOD.....				.12	.56	.35	.83	.10	.27	.78		.25	1.00	.99	.76	.97		.93	.67	.58
Seeds.....								1	2	1		1		2	3	1		1	1	8
1. Exogens.....							.50		.14	.25		.08		48	.16	.22		.08	.50	.10
Seeds.....								1	+									3		3
Compositæ (Pollen).....																		.17		.03
Ambrosia.....																		.17		.03
2. Endogens.....				.10	.11	.35	.30	.10		.28				.25	.34			.23	.10	.17
Gramineæ.....				.10	.11	.35	.30			.28				.25	.34			.23	.10	.17
Seeds.....							1		1	*				1				1		4
Pollen.....					.1	.2	.35								.05			+		.02
Phleum (seeds).....														1	4					.02
3. Hepaticæ.....														.25	.21					.06
4. Algæ.....																				.02
Protococcus.....								1				1								.01
5. Fungi.....				1	3		1	1	3	1		1	1	2	3			5	1	.23
Coprinus.....				+	.45		.03	+	.07	.21		.14	1.00	.11	.04			.13	.07	.09
Phoma.....						.2	.45													.01
Coleosporium.....																				.02
Dematiei.....																				.01
Helminthosporium.....						2	+		1				1.00				2	+		.01
Cladosporium.....														.01	.01					.01
Peronospora.....										1					1	+		1		.03
Ramularia.....															1					.01
															10					.01

CARABIDÆ AND CANKER-WORMS.

	Calosoma.	Pasimachus.	Scarites.	Galerita.	Calathus.	Platynus.	Evarthus.	Pterostichus.	Amara.	Dicælus.	Chlænus.	Anisodactylus.	Amphasia.	Harpalus.	Summary.
No. of Specimens.	10	2	4	13	3	1	2	3	1	1	16	10	1	3	70
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.														
ANIMAL FOOD.	10	2	4	13	3	1	2	3	1	16	1	1	2	59	
	1.00	1.00	1.00	.94	.68	1.00	1.00	.80	1.00	.92	.09	.25	.35	.77	
I. MOLLUSCA.									1.00						.02
II. INSECTA. ....	.50		.50	.85	.68		1.00	.13		.12	.09	.25	.35	.42
Larvæ. ....				.2						1				3
1. <i>Hymenoptera</i> (ants)							1							1	
2. <i>Lepidoptera</i> (larvæ) .....				.8	.1		.05	.1		.8			.1	21
<i>Anisopteryx vernata</i> .....				.56	.33		.90	.11		.41			.33	.26
<i>Noctuidæ</i> .....				.7	.1		.2			.5			.1	.16
3. <i>Diptera</i> .....				.52	.33		.90			.26			.33	.21
<i>Culicidæ</i> .....				.1						.2				.3
4. <i>Coleoptera</i> .....				.01						.12				.03
<i>Telephoridæ</i> .....				.3	.1		.1			.1	.1			.7
III. ARACHNIDA .....				.07	.02		.05			.01	.09			.03
Spiders .....							.1							.1
Mites .....							.05							.1
IV. MYRIAPODA										1				.01	
(<i>Geophilus</i>) .....										.06				.1
V. VERMES (<i>Lumbricus</i>) .....										.1				.4
VEGETABLE FOOD .....				.05						.02				.01
Seeds .....				.1						.06				.1
1. <i>Exogens</i> .....				.06						.02				.1
2. <i>Endogens</i> .....										.01				.1
Graminæ .....										.02				.1
Seeds .....										.04				.1
3. <i>Fungi</i>									1					.1	
<i>Peronospora</i>									†					.1	
<i>Ascomycetes</i> .....										.04				.1
										.02				.1	

COCCINELLIDÆ.

	Miscellaneous.				Chinch-bugs.				General.				
	Hippodamia.	Coccinella.	Brachyacantha.	Summary.	Hippodamia.	Coccinella.	Cycloneda.	Summary.	Hippodamia.	Coccinella.	Cycloneda.	Brachyacantha.	Summary.
Number of Specimens.....	15	5	1	21	14	1	3	18	29	6	3	1	39
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.												
ANIMAL FOOD.....	.44	.64		.47	.25		.32	.25	.35	.53	.32		.37
I. INSECTA.....	.39	.64		.43	.25		.32	.25	.32	.53	.32		.35
1. <i>Lepidoptera</i>	+			+	.01			.01	.01				.01
Larvæ.....					.01			.01	.01				.01
2. <i>Hemiptera</i>.....	.29	.64		.36	.21		.32	.22	.25	.53	.32		.29
Aphides.....	.29	.64		.36	.11		.32	.14	.20	.53	.32		.26
Siphonophora granariæ.....					.05		.24	.08	.02		.24		.03
Chinch-bugs.....					.10			.08	.05				.03
3. <i>Neuroptera</i> (Podura).....	.01			.01					+				+
II. ARACHNIDA (Mites).....	.01			.01	+			+	.01				+
III. MYRIAPODA (Geophilus).....	.01			.01					.02				.02
VEGETABLE FOOD.....	.56	.86	1.00	.53	.75	1.00	.68	.75	.65	.47	.68	1.00	.63
Pollen.....	.03	+		.02					.01	+			.01
1. <i>Exogens</i> (Pollen).....	.7			.7	.13		.3	.16	.20		.3		.23
Compositæ.....	.13			.09	.07		.47	.13	.10		.47		.11
Taraxacum.....	.07			.05					.04				.03
Ambrosia.....					2			2	2				2
Polygonum.....	1			1	1			1	2				2
Coniferae.....	+			+	*			+	+				*
2. <i>Endogens</i>.....	.05			.04					.03				.02
Gramineæ.....	.05			.04					.03				.02
Pollen.....	.05			.04					.03				.02
3. <i>Lichenes</i>.....	.02	.04		.02	.06		.03	.05	.04	.03	.03		.04
Physcia.....	.01			+	6		+	7	.01		+		.01
4. <i>Fungi</i>.....	.33	.32	1.00	.36	.61	1.00	.18	.56	.46	.44	.18	1.00	.45
Myxogastres.....	1			+					+				*
Sphaeronemei.....	1			.01					1				*
Septoria.....	1			.01	7		1	8	8		1		9
Ustilago.....	1	.08		.02	*			*	*		.07		*
Uredo.....					1			*	+				*
Helminthosporium.....	6	1	1	8	11		1	12	17	1	1	1	20
Macrosporium.....	3	.10	1.00	.17	*		*	*	*	.08	*	1.00	*
Cladosporium.....	3			.04	7		1	8	10				11
Peronospora.....	3			.02	3		2	15	16				18
Menispora.....	1			.01	7		*	*	10				10
	1			+	*			*	*				*

ERRATA.

Page 6, line 12 from bottom; page 8, line 15; page 11, line 2; for *Cydnidæ*, read *Pentatomidæ*.

Page 17, line 9, before *Vireo*, omit *and*.

Page 23, above ARACHNIDA, for *Cydnidæ*, read *Pentatomidæ*.

Pages 25 and 27, above *Orthoptera*, for *Cydnidæ*, read *Pentatomidæ*.

Page 28, lines 2 and 8, for *Graphorhinus vadosus*, read *Epicærus imbricatus*.

Page 64, under *Hemiptera*, for *Siphonophora granariæ*, read *Aphis maidis*.

Page 69, line 5 from bottom, for *fresh-water*, read *local*.

Page 78, line 1, after *all*, insert *the*.

Page 82, line 7, for *character*, read *characters*.

Page 91, line 5, for *consisted*, read *consists*.

Page 92, line 2 from bottom, for *more*, read *most*.

Page 97, line 11, for *fory-six*, read *forty-six*.

Page 99, line 2, for *witn*, read *with*.

Page 101, lines 12 and 13 from bottom, for *structure*, read *structures*.

Page 105, line 23, for *aération*, read *aëration*.