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STUDIES

OF THE

FOOD OF BIRDS, INSECTS AND FISHES,

MADE AT THE

ILLINOIS STATE LABORATORY OF NATURAL HISTORY,

AT

NORMAL, ILLINOIS.

EDWARD HINE, PRINTER, ADAMS STREET, CORNER HARRISON, PEORIA.

MAY, 1883.

THE REGULATIVE ACTION OF BIRDS UPON INSECT OSCILLATIONS.

By S. A. FORBES.

Attention has already been repeatedly called in these studies to the fact (fundamental to this investigation) that the principal injuries due to insects are done by a few species, existing, for a time, in numbers far above the average, and soon to retire again to a much lower limit. As the number of a species which reach maturity is determined by the checks on its multiplication, it follows that these oscillating species are held in check by variable forces, and to the variations in these checks we must look for an explanation of their oscillations. On the other hand, we must expect to find that those insects whose numbers remain relatively constant from year to year are under the control of restraining influences of a much more uniform character than the preceding class.

Concerning the effects of birds upon insect life, and through this upon the interests of agriculture, there are therefore three questions to answer: —

1. Do birds originate any oscillations among the species of insects upon which they feed? That is, are their food habits ever so inconstant from year to year that species which are at one time principal elements of their food, are at other times neglected and allowed to multiply without restraint?

2. Do birds prevent or restrain any oscillations of insects now noxious, or capable of becoming so if permitted to increase more freely? That is, do they bring to bear upon any such species a constant pressure so great that those insects would increase unduly if this pressure were removed by the destruction of the birds?

3. Do they do anything to reduce existing oscillations of injurious insects? Do they sometimes vary their food habits so far as to neglect their more usual food and take extraordinary numbers

of those species which, for any reason, became superabundant for a time ?

For the purpose of answering these questions, two separate lines of investigation are necessary. For the first two we require a knowledge of the food habits of the various species of birds under ordinary circumstances, when the conditions of life are of average character, and especially when no species of insects are unusually and excessively abundant. On the other hand, for an answer to the third question we must look to the food habits of the birds under extraordinary circumstances, where the opposite condition of affairs prevails. We must learn to what extent birds depart from their usual practices when confronted by an uprising of some insect species. If they concentrate for its suppression, they must assist more or less effectively to reduce to order the disturbed balance of life; but if they remain indifferent to this condition of things, their influence is *nil.*

The present paper is a contribution to a discussion of the last of the above questions. As a striking and conclusive example of an extraordinary condition of insect life, and of the food of birds in the presence of a disturbed balance of nature, I selected an orchard which had been for some years badly infested by canker-worms, shot a considerable number of birds therein for two successive years, representing nearly all the kinds seen in the orchard, made full notes of the relative abundance of the species, examined carefully the contents of all the stomachs obtained, with reference not only to the presence of canker-worms but of all other insects as well, and tabulated the results as the basis of this paper. Besides preparing as full an account of the food of these birds as practicable, I have brought the summaries on these tables into comparison with those derived from birds of the same species shot in ordinary situations during the same month. These comparisons have been confined to a few of the kinds obtained in the orchard, for the reason that most were not found there in sufficient number to give a fair idea of the average food of the species. The collections were made in an orchard of forty-five acres of bearing apple-trees (belonging to Mr. J. W. Robison) in Tazewell County, Ill., which had been infested by canker-worms for about six years. As a result of their depredations, a considerable part of the orchard had the appearance, from a little distance,

of having been ruined by fire. Closer examination of the trees most affected showed that the branches, stripped of every vestige of green, were festooned with the webbing left by the worms. To the webs the withered remnants of the leaves adhered as they fell, the very petioles having been gnawed off at the twigs. Not one per cent. of the trees were uninjured, and these were invariably on the outer part of the orchard. Those which had been attacked several years in succession were killed; and there was a large area in the midst of the orchard from which such trees had been removed. One did not need to enter the enclosure to learn that the birds were present in extraordinary numbers and variety. From every part of it arose a chorus of song more varied than I had ever heard in any similar area at that season of the year. Most of the common summer residents were found there; and upon a second visit in 1882 many of the migrant species likewise occurred. The first collection was made on the 24th of May, 1881, and the second on the 20th of the same month im the following year. The season was less advanced at the time of the second collection than at the first, so that the actual difference between the two was probably not less than two weeks. At the first visit fifty-four birds were taken, representing twenty-four species, and seven other species were noted in the orchard of which no specimens were obtained. On the second visit ninety-two birds were shot, representing thirty-one species, and four other species were seen. In 1881 the worms were nearly all fully grown, and many of them had already entered the ground for their transformation, so that the larvæ were less abundant than they had been earlier. In 1882 most of them were about half-grown, only a few having reached adult size. They were distinguishable with difficulty upon the leaves of the trees; but when a large branch was shaken or jarred, from a dozen to twenty would expose themselves by spinning down and hanging at the end of a thread. The owner of the orchard informed me that they were about twice as abundant the preceding season.

TURDIDÆ. Thrushes.

Turdus migratorius, L. Robin.

This species was abundant and nesting in the orchard. Nine specimens were obtained in all, three in 1881 and six in the fol-

lowing year. The food was wholly animal, neither fruit nor any other kind of vegetation having been taken by any of the birds. Only three of the above number had eaten canker-worms, which composed, as nearly as could be estimated, about one-fifth of the food of the entire group. Insects made ninety-three per cent., the remainder consisting of a common species of myriapod (five per cent.), earth-worms, and gasteropod mollusks. Ants were eaten by these birds only in trivial numbers. Diptera, Orthoptera and spiders were conspicuous by their entire absence. Cut-worms were extraordinarily prominent in the food, making twenty-eight per cent. of the whole. Half of them consisted of a single large, injurious species (*Nephelodes violans*). Among the Coleoptera, which amounted to thirty-six per cent. of the whole, the Scarabæidæ and Elateridæ were the principal elements, the former represented by eighteen per cent., and the latter by eleven. Among the Scarabæidæ was a species known as a vine leaf-chafer (*Anomala binotata*), which made fourteen per cent. of the food. This insect was scarcely less abundant than the canker-worm, and appeared in extraordinary numbers in the food of nearly all the species of birds examined, although it had not attracted the attention of the owner of the grounds. I searched a small vineyard adjacent, but saw no signs of unusual injury to the leaves. Carabidæ, although common in the orchard, had scarcely been touched by the robins, only a single specimen of the family occurring. Hemiptera were found but in trivial numbers, representing about equally the families Coreidæ and Cydnidæ. Hymenoptera were still less abundant, composing only one per cent. of the food.

MIMUS CAROLINENSIS, L. CATBIRD.

This species was very common, and thoroughly at home among the trees, where it was doubtless nesting. Fourteen specimens were taken, three at the first visit and eleven at the second. With the exception of two per cent. of myriapods, their food consisted entirely of insects. Canker-worms had been eaten by eight of the birds, but not in any great number, as they composed but fifteen per cent. of the food of the species. A few cut-worms had been taken, and a larger number of other caterpillars, bringing the total for Lepidoptera up to about one-fourth of the food.

The catbird had shown its usual preference for ants, eating fourteen per cent. of these insects. These birds had taken an unusual number of Coleoptera, which made more than half the food, chiefly Scarabæidæ. About two-thirds of them belonged to the single species (*Anomala binotata*) mentioned above under the food of the robin. Three of these birds had likewise eaten large June bugs. Elateridæ and their larvæ occurred only in trivial quantities, while Carabidæ amounted to four per cent., chiefly Anisodactylus. As in the robin, Diptera, Orthoptera, and Arachnida, were not represented in the food.

HARPORHYNCHUS RUFUS, L. BROWN THRUSH.

This bird was not common in the orchard, and only four specimens were taken. The food of these was entirely animal, an unexpected circumstance, as the brown thrush usually feeds largely upon grain. Six per cent. of the food consisted of thousand-legs, and insects made the entire remainder. Lepidoptera were about one-fifth of the food, and half of these were canker-worms. Like the preceding species, this bird had eaten an enormous number of beetles, which amounted to two-thirds of its food. Twelve per cent. of the whole was Carabidæ, chiefly a species of Chlænius. Scarabæidæ stand at forty-four per cent., largely Diplotaxis, Melolontha, and Anomala. Six per cent. were Elateridæ, and three per cent. Rhynchophora. No specimens of the remaining orders had been eaten by these birds.

Summary of the Family.

Treating, now, of the twenty-seven thrushes mentioned as one group, we find that none of them had eaten any vegetation whatever; that ninety-six per cent. of their food consisted of insects (myriapods and earth-worms making up the remaining four per cent.); that sixteen per cent. was canker-worms; and only four per cent. predaceous beetles. The Anomala previously mentioned made just a fourth of their entire food, other Scarabæidæ bringing up the average of that family to thirty-eight per cent. Click beetles (Elateridæ) with their larvæ were five per cent. of the whole, and snout beetles (Rhynchophora) two per cent.

SAXICOLIDÆ. Bluebirds.

SIALIA SIALIS, L. BLUEBIRD.

This species was not at all abundant in the orchard in either year. Only one was taken in 1881, and four in 1882. All but two per cent. of the food of these five specimens consisted of insects, spiders making the remainder. Canker-worms were twelve per cent. of the food, and other Lepidoptera five per cent. additional. Two-thirds of the food consisted of Coleoptera. Carabidæ made more than one-third (twenty-three per cent.), belonging chiefly to a species (*Anisodactylus baltimorensis*) which depends largely upon vegetable food. Four of the birds had eaten *Anomala binotata*, which made thirty-six per cent. of the food of the whole. Five per cent. was Chrysomelidæ, and fifteen per cent. Hemiptera, all belonging to the family Cydnidæ.

PARIDÆ. Chickadees.

PARUS ATRICAPILLUS, L. BLACK-CAPPED CHICKADEE.

This little bird, unfortunately, was not at all common in the orchard; and only two specimens were taken, one in each year. Sixty-one per cent. of their food consisted of canker-worms, eaten by both the birds, and Coleoptera made the entire remainder. These were nearly all Cerambycidæ (*Psenocerus supernotatus*) and Rhynchophora of undetermined species, twenty-five per cent. of the former, and ten of the latter.

TROGLODYTIDÆ. Wrens.

TROGLODYTES DOMESTICUS, Bartr. HOUSE WREN.

Several specimens of this little species were observed, some of them evidently nesting. The food was chiefly insects,—all, in fact, but six per cent. of spiders and one of thousand-legs. Nearly half the food of these birds consisted of canker-worms, and other Lepidoptera and their larvæ brought the average of the order up to fifty-nine per cent. A few gnats and other Diptera (four per cent.) and five per cent. of ants were also noted. Coleoptera and Hemiptera were taken in nearly equal quantities, thirteen per cent. of the former and ten of the latter. Two of the

birds had eaten *Psenocerus supernotatus*, amounting to four per cent. of the food, and the other Coleoptera were scattered through the families Carabidæ, Nitidulidæ, Scarabæidæ, Elateridæ and Calandridæ. The Hemiptera were represented by trivial numbers of four families, including a few chinch bugs.

MNIOTILTIDÆ. Warblers.

HELMINTHOPHAGA PEREGRINA, Wils. TENNESSEE WARBLER.

A single specimen of this little warbler was taken in 1882. Four-fifths of its food consisted of canker-worms, and all the remainder of a single species of beetle (*Telephorus bilineatus*).

DENDRŒCA ÆSTIVA, Gmel. SUMMER YELLOW BIRD.

This bird, common every where at this season, was also abundant in the orchard. Five specimens were shot in all. The food was insects, excepting six per cent. of spiders. Two-thirds of the total amount eaten by all of the birds consisted of canker-worms. Coleoptera were twenty-three per cent. of the whole amount, six per cent. being Aphodius, and twelve per cent. *Psenocerus supernotatus*, already frequently mentioned. Carabidæ and Calandridæ were represented by insignificant ratios, and Lampyridæ by a single Telephorus eaten by one of the birds. One per cent. of Hemiptera, and two of Hymenoptera complete the record.

DENDRŒCA PENNSYLVANICA, L. CHESTNUT-SIDED WARBLER.

Two specimens of this abundant migrant were shot in the orchard in 1882. Like the preceding warbler, two-thirds of their food consisted of canker-worms, and an additional ten per cent. of other caterpillars. A few ants were eaten by both of the birds. Eleven per cent. of Coleoptera, likewise eaten by the two, was about equally divided between some undetermined Scarabæidæ and *Psenocerus supernotatus*. One of the birds had eaten plant-lice, which amounted to five per cent. of the food; and both had taken ants to the amount of six per cent.

DENDRŒCA STRIATA, Forst. BLACK-POLL WARBLER.

Four of these birds were shot in 1882. Some undetermined seeds found in the crop of one of them reduced the insect ratio

to ninety-five. Again two-thirds of the food consisted of canker-worms. The same little borer (*Psenocerus*) eaten by so many of the smaller birds in this orchard, made fifteen per cent. of the food; and an Aphodius and an undetermined carabid bring up the ratio of the Coleoptera to nineteen per cent. Four per cent. of ants, a few gnats (five per cent.), and traces of Hemiptera and mites were the only other elements detected.

DENDRŒCA VIRENS, Gm. BLACK-THROATED GREEN WARBLER.

A single specimen of this migrant was shot in 1882. Seventy per cent. of its food consisted of canker-worms, fifteen per cent. of Psenocerus, and five of undetermined Hemiptera. The remaining ten per cent. was made up of trivial numbers of Hymenoptera, gnats, coleopterous larvæ and mites.

GEOTHLYPIS TRICHAS, L. MARYLAND YELLOW-THROAT.

This resident warbler occurred but sparingly in the orchard. One specimen was seen in 1881, and two were obtained in 1882. Lepidoptera made four-fifths of their food, about equally canker-worms and undetermined caterpillars. A few Staphylinidæ and some specimens of Psenocerus composed the eight per cent. of Coleoptera. A small hemipter (*Piesma cinerea*) amounted to five per cent., and four per cent. was gnats.

Summary of the Family.

Of the warbler family as a whole, as represented by these fifteen specimens, I need only remark that fourteen of the birds had eaten canker-worms, which composed nearly or quite two-thirds of the food of the group; that ten per cent. consisted of *Psenocerus supernotatus;* and that the remaining averages, with the exception of six per cent. of undetermined caterpillars, were so much subdivided as to have little or no significance.

VIREONIDÆ. Vireos.

VIREO GILVUS, V. WARBLING VIREO.

Three specimens of this little bird were shot, of purely insectivrous habit. They had eaten canker-worms to the amount of forty-four per cent.; and other caterpillars made thirty-five per

cent. additional. A few Coleoptera (fifteen per cent.) of which one-third were carabid larvæ, and three per cent. of Cydnidæ (*Podisus*), were the only other important elements. *Anomala binotata* (eight per cent.), Telephorus, and an undetermined long-horn, were the other Coleoptera.

AMPELIDÆ. Wax-wings.

AMPELIS CEDRORUM, V. CEDAR WAX-WING.

A flock of about thirty of these birds was repeatedly started in the orchard during the first visit, but none were seen in 1882. Seven of the flock were shot, and the contents of their stomachs carefully studied. With the exception of a few Aphodii eaten by three of the birds in numbers too insignificant to figure in the ratios, the entire food of all these birds consisted of canker-worms, which therefore stand at an average of one hundred per cent. The number in each stomach, determined by actual count, ranged from seventy to one hundred and one, and was usually nearly a hundred. Assuming that these constituted a whole day's food, the thirty birds were destroying three thousand worms a day, or ninety thousand for the month during which the caterpillar is exposed.

HIRUNDINIDÆ. Swallows.

PETROCHELIDON LUNIFRONS, Say. CLIFF SWALLOW.

This species was nesting in great numbers under the eaves of a barn at the edge of the orchard, and many of the birds were continually circling through the air. A single specimen was shot, and found to contain nothing but the very abundant scavenger beetle (*Aphodius inquinatus*), with about two per cent. of undetermined Hemiptera.

FRINGILLIDÆ. Finches.

ASTRAGALINUS TRISTIS, L. AMERICAN GOLDFINCH.

A flock of these birds passed through the orchard, but only a single one was shot. No canker-worms had been eaten by it; but about seventy per cent. of its food consisted of undetermined seeds, and the remainder of a harpalid beetle.

COTURNICULUS PASSERINUS, Wils. YELLOW-WINGED SPARROW.

A single specimen of this bird, shot in 1881, contained spiders thirty per cent., seeds of pigeon grass (*Setaria*) fifteen per cent., an unrecognized beetle five per cent., and some undetermined caterpillars, certainly not canker-worms.

SPIZELLA DOMESTICA, Bart. CHIPPING SPARROW.

This species was not common in the orchard in 1881, and only a single specimen was obtained; but in the following year it was found much more abundant, and seven additional were taken. About one-third of the food consisted of caterpillars, half of which were recognizable as canker-worms. A large number of gnats (twenty-eight per cent.), nearly as many Coleoptera, (principally Scarabæidæ, including nine per cent. of Anomala), and six per cent. of Hemiptera, are all the other noteworthy items.

SPIZELLA AGRESTIS, Bart. FIELD SPARROW.

This species was less abundant than the preceding, and was represented by only three specimens. With the exception of five per cent. of gnats, and one of Hemiptera, the food of this bird was equally divided between Lepidoptera and Coleoptera. Nearly half the former consisted of canker-worms, while the Coleoptera were represented by Histeridæ, Scarabæidæ (chiefly the scavengers), Monocrepidius and Rhynchophora.

SPIZA AMERICANA, Gmel. BLACK-THROATED BUNTING.

This bird was the most abundant species in 1881, though but few were seen during the following May. Eleven were shot at the first visit and three at the second. With the exception of a little wheat eaten by two of the birds, and a trace of undetermined seeds, the food consisted almost entirely of insects and mollusks, eighty-eight per cent. of the former and six of the latter (Helix). Ten of these birds had eaten canker-worms, which made forty-three per cent. of the food of the entire group; Lepidoptera as a whole composing two-thirds of the food. Among the twenty-two per cent. of Coleoptera, we note Harpalus and Histeridæ, each four per cent., Aphodius and Anomala likewise each four per cent., and Sphenophorus and other Rhynchophora, two per cent.

ZAMELODIA LUDOVICIANA, L. ROSE-BREASTED GROSBEAK.

Only two were seen, and both were killed. A very few canker-worms were found (five per cent.) with fifty-eight per cent. of other caterpillars. About half the fifteen per cent. of Coleoptera were Rhynchophora, the remainder being *Anomala binotata*, one of the Lampyridæ, and undetermined specimens. One-fifth of the food consisted of seeds not recognized.

PASSERINA CYANEA, L. INDIGO BIRD.

This bird, noted as common in 1881, was by far the most abundant species in the orchard at the second visit. Eighteen specimens were shot, two in the first and the remainder in the second year. Although this bird is one of the typical finches, only three per cent. of its food consisted of seeds, chiefly Setaria and Compositæ. Canker-worms made fifty-nine per cent., eaten by all the birds but one, and other caterpillars an additional eight per cent. With the exception of a trace of Hymenoptera, the remainder of the food consisted entirely of beetles, about one-third of which were *Anomala binotata*.

Summary of the Family.

Only seven per cent. of the food of the forty-seven members of this family (commonly called seed-eaters) consisted in fact of seeds; and insects made up all but two per cent. of the remainder. The most interesting items on the general list are canker-worms forty per cent., predaceous beetles (Carabidæ) two per cent., and *Anomala binotata* six per cent.

ICTERIDÆ. Blackbirds.

MOLOTHRUS ATER, Bodd. COWBIRD.

A single wandering specimen of this bird contained only Scarabæidæ, including Aphodius, and a few other Coleoptera, with about sixty per cent. of corn and some seeds of Polygonum and other plants.

AGELÆUS PHŒNICEUS, L. RED-WINGED BLACKBIRD.

Two specimens of this bird, which were also accidentally in the orchard, had fed about equally upon insects and upon wheat and

other seeds. The Lepidoptera (twenty-seven per cent.) were nearly all the larvæ of *Nephelodes violans*. Of the Coleoptera (eleven per cent.), part were Anomala and Elateridæ, and the remainder consisted of specimens of *Tanymecus confertus*, eaten by one of the birds. A grasshopper had also been taken by one, making ten per cent. of the food; and traces of Hemiptera were recognized.

ICTERUS GALBULA, L. BALTIMORE ORIOLE.

Not common. Three were shot. These had fed only on insects,—Lepidoptera forty per cent. and Coleoptera sixty per cent., the former all canker-worms, and the latter chiefly *Anomala binotata* (fifty per cent.). Six per cent. of Cerambycidæ and two of Rhynchophora should also be mentioned.

ICTERUS SPURIUS. L. ORCHARD ORIOLE.

This bird was common in 1881, although but two were shot; but was not noticed the next year. More than three-fourths of the food of these consisted of canker-worms, and other caterpillars made an additional twenty per cent., leaving but three per cent. for ants.

QUISCALUS PURPUREUS ÆNEUS, Bartr. BRONZED GRACKLE.

Wandering specimens of the grackle were seen, and a few were apparently roosting in the trees at night. But three were shot, all of which had fed chiefly upon corn, which amounted to sixty-two per cent. of their food. Fragments of a crawfish were found in the stomach of one. Half the thirty per cent. of Coleoptera were Carabidæ, including a specimen of *Calosoma calidum*, and the remainder were nearly all Lucanidæ (Dorcus, eight per cent.) and undetermined Elateridæ.

Summary of the Family.

The five species of this family mentioned were represented by but eleven specimens, which, taken together, were found to have made two-thirds of their food of insects, the remaining third of corn and wheat with a few seeds of weeds. Canker-worms, eaten by the orioles, only amounted to one-fourth of the food of the whole,

and Coleoptera to a little more than another fourth. Of these, Carabidæ made four per cent., Cerambycidæ two, Rhynchophora one, and *Anomala binotata* fourteen.

TYRANNIDÆ. Flycatchers.

Tyrannus carolinensis, L. Kingbird.

This species was not uncommon, but only three were shot. Two of these, to my surprise, were found to have eaten canker-worms, which made more than a fourth of the food of the whole. Five per cent. of the remainder consisted of undetermined Hemiptera, and all the balance was Coleoptera. Seven per cent. was Elateridæ, two Lampyridæ, and more than fifty-eight Scarabæidæ, all Anomala except thirteen per cent. of *Aphodius inquinatus*, eaten by one of the birds.

Contopus virens, L. Wood Pewee.

Three of these were shot, none of which had taken canker-worms. Their food consisted chiefly of flies and gnats, which amounted to fifty-five per cent. Thirteen per cent. of Aphodius and ten per cent. of Ips, with a few ants and other Hymenoptera, are also worthy of mention.

Empidonax trailli, Aud. Traill's Flycatcher.

Two specimens, shot in 1882, had eaten only insects, one-fourth of which were canker-worms, and one-third Ichneumonidæ. Another fourth consisted of Coleoptera, nearly half of which were Anomala; and ten per cent. were ants and other Hymenoptera.

Empidonax flaviventris, Bd. Yellow-bellied Flycatcher.

A single specimen had eaten a number of Lepidoptera and their larvæ, but no canker-worms. Half the food was Coleoptera, nearly all Aphodius and *Anomala binotata*,—fifteen per cent. and twenty-five per cent. respectively. The little Psenocerus was likewise taken by this bird, and a specimen of Hymenarcys (Hemiptera).

Summary of the Family.

The nine flycatchers taken had eaten only insects, of which nearly half were Coleoptera, and the remainder were about equally distributed between the Hemiptera, Lepidoptera, and Diptera. Canker-worms make fifteen per cent. of the whole, and *Anomala binotata* seventeen per cent. The Scarabæidæ include all but ten per cent. of the Coleoptera.

CUCULIDÆ. Cuckoos.

COCCYZUS ERYTHROPHTHALMUS, Wils. BLACK-BILLED CUCKOO.

Three-fourths of the food of a single specimen shot consisted of canker-worms, other caterpillars making an additional twenty per cent. *Anomala binotata* was the only remaining element.

PICIDÆ. Woodpeckers.

MELANERPES ERYTHROCEPHALUS, L. RED-HEADED WOODPECKER.

This bird was abundant in the orchard, evidently nesting in the trees, although but four specimens were shot. Two of these had eaten corn, which amounted to twenty per cent. of the food. Fifteen per cent. was canker-worms, and twenty-four per cent. Carabidæ (eaten by two of the birds), including Calosoma, Scarites, and several Harpalids. Twenty-nine per cent. of Scarabæidæ embraced a Canthon and some specimens of *Anomala binotata*. Melanotus and other spring-beetles were also eaten by two of the birds.

COLAPTES AURATUS, L. FLICKER.

A single specimen, killed in 1881, had fed only on ants, the usual aliment of the bird.

COLUMBIDÆ. Doves and Pigeons.

ZENAIDURA CAROLINENSIS, L. MOURNING DOVE.

Several mourning doves were seen, and a single specimen was taken. Three-fourths of the food of this was corn, and the remainder the seeds of some leguminous plant.

PERDICIDÆ. Quails and Partridges.

ORTYX VIRGINIANA, L. QUAIL.

Two quails were shot, among half a dozen seen. All but four per cent. of their food consisted of corn and other seeds, chiefly those of Compositæ. A single chrysomelid, a rhynchophorous beetle, and a carabid, were the only insects found.

Besides the species of birds above mentioned, the following were noted rarely in the orchard, but no specimens were secured: and *Vireo olivaceus*, *Sturnella magna*, *Cyanurus cristatus*, and *Chætura pelasgica*. The blue jay was seen eating canker-worms in the trees. The total number of species observed in the orchard wa therefore forty, and the number of specimens obtained and studied was one hundred and forty-one, representing thirty-six of the species. Twenty-six of these species had been eating canker-worms, which were found in the stomachs of eighty-five specimens. That is to say, seventy-two per cent. of the species, and sixty per cent. of the specimens, had eaten the worms. Taking the entire assemblage of one hundred and forty-one birds as one group, we find that thirty-five per cent. of their food consisted of canker-worms; and if we exclude the species evidently merely accidental in the orchard, the average of canker-worms in the food of those properly belonging there rises to about forty per cent.

For a correct estimate of the probable effect of the birds in limiting the increase of the canker-worm, it is necessary to take into account some of the features of its natural history. The larval life of the insect lasts about one month, after which it enters the ground and pupates, where it remains until the following spring. The imagos, the females of which are wingless, emerge about the middle of April. They lay their eggs upon the bark of the trees, usually at night, remaining concealed upon the ground by day under fallen leaves and other rubbish. The eggs remain upon the trees about a month before the worms emerge, when the latter crawl up the trunk and commence their attacks upon the leaves. The pest is consequently exposed to destruction from the time it emerges until it disappears again, the adults falling an easy prey to birds which search the ground for

food, and the eggs to the small species which pry about the trunks of trees. The entire period during which the insect is doubtless fed upon by birds will usually amount to somewhat more than two months.

Besides the abundance of the canker-worms noted in the food of these birds, it is evident that two or three other species of insects occurred in this situation in extraordinary numbers, especially the vine leaf-chafer (*Anomala binotata*) and a small borer (*Psenocerus supernotatus*). The purple cut-worm (*Nephelodes violans*) was also somewhat commoner than usual. The Anomala was eaten by thirty-nine of the specimens, representing fifteen species, and amounted to eleven per cent. of the food of all the birds taken in the orchard. Many of these were too small to feed upon so large an insect, and a better illustration of the abundance of this beetle may be gathered from the food of the thrushes and blue-bird. Of thirty-two specimens of these families, nineteen had eaten the vine leaf-chafer, which amounted to twenty-seven per cent. of the food of all. Only fourteen of the same birds had eaten the canker-worm, which amounted to less than twenty per cent. of the food. It seems likely, therefore, that some of these birds were attracted to the orchard, not by the canker-worms, but by the superabundance of Anomala. The unusual frequency of *Psenocerus supernotatus*, a small long-horned beetle found upon the trees, is shown by the fact that of the twenty-five small arboreal birds (Paridæ, Troglodytidæ, and Mniotiltidæ), thirteen had eaten this beetle, which composed nearly one-tenth of their food.

We have next to make the comparison of the food taken in the orchard by the species most abundant there, with the food of the same species, taken elsewhere under ordinary circumstances. For the purpose of this comparison I have selected the robin, the catbird, the black-throated bunting (*Spiza americana*), and the indigo bird (*Passerina cyanea*). In the table of the ordinary food of the robin for May, published in Bulletin 3 of this series, as represented by fourteen specimens, caterpillars amounted to but twenty-three per cent., whereas in the orchard they rise to fifty-four per cent. This difference between the averages is almost exactly accounted for by the ratios of canker-worms and *Nephelodes violans* not appearing on the former table; these together amounting to thirty-five

per cent. Notwithstanding the number of Anomala eaten in the orchard, the ratios of the Scarabæidæ are substantially the same, as the ordinary food of the robin in May consists largely of June beetles. The surplus of Lepidoptera seems to be balanced by a deficiency in all the other orders, no one of which rises to the average of its ordinary food in May. The loss is greatest, however, in the Diptera, which drop from eleven per cent. to nothing.

Comparing the record of the fourteen catbirds shot in the orchard with that of twenty-two obtained in miscellaneous situations, we note, first, that the caterpillars on the first table are more than twice those of the second,—twenty-six in the one, and twelve in the other; and that this difference is evidently due to the fifteen per cent. of canker-worms taken by the birds of the first group. This shows that the catbird, like the robin, had simply added the canker-worms eaten to its usual ratio of caterpillars. A more striking difference is shown in the totals of Coleoptera, which stand at fifty-six per cent. in the orchard birds, and twenty-three in the others. This, again, is evidently due to the abundance of *Anomala binotata;* for when the ratio of this insect is subtracted from the total of Coleoptera, the remainder is twenty per cent. as against twenty-three of the ordinary food. These excessive ratios of Lepidoptera and Coleoptera are compensated by deficiencies in the Diptera, Arachnida, Myriapoda and Orthoptera, especially in the three first named groups. The decided preference of this bird for ants is shown by the fact that the usual ratio of these insects is scarcely diminished, fourteen per cent. having been taken in the orchard and eighteen elsewhere.

Fourteen of the black-throated bunting (*Spiza americana*), killed in the orchard, are to be contrasted with twelve shot in May from various situations. A striking difference is seen at once in the insect ratios, which amount respectively to eighty-eight and forty-seven per cent. This surplus of insects eaten by the orchard birds is readily traced to the orders Lepidoptera and Coleoptera. Of the former these birds had eaten more than three times their ordinary average, and of the latter nearly four times the usual amount. The excess of Lepidoptera is clearly due, as usual, to the presence of the canker-worms, since the balance left

after subtracting the canker-worm ratio from the average of that order taken by the first group, differs by only three per cent. from the average taken by the second group. The discrepancy in the ratios of Coleoptera is not so easily explained, but is distributed among several genera of Scarabæidæ and the small scavenger beetles. The excess of these two orders is compensated principally by diminished ratios of vegetation, which amount to only six per cent. in the birds shot in the orchard, and fifty-two per cent. among those taken through the country at large. Diptera and all the lower orders of insects as well as Arachnida and Myriapoda, are also omitted from the food of the orchard birds.

Insects composed ninety-seven per cent. of the food of eighteen indigo birds (*Passerina cyanea*) shot in the orchard, and but fifty-seven per cent. of the food of fifteen individuals taken elsewhere, the balance in both cases being seeds, chiefly Setaria, Polygonum and wheat. The excess of insects in the orchard specimens appears under Lepidoptera and Coleoptera, the former sixty-seven per cent., the latter twenty-nine, as compared with twenty-eight and nineteen per cent. respectively, in the other group. The Lepidoptera of the orchard birds are nearly all canker-worms, as are likewise ten per cent. of those taken by the specimens from various situations. The difference in the ratio of Coleoptera taken by the two groups was exactly compensated by the ten per cent. of *Anomala binotata* eaten in the orchard. The excess of caterpillars and beetles taken by the former group, is partly compensated also by the almost total disappearance of all other insects from the food.

What, now, may we conclude, from the above data, respecting the influence of birds upon such entomological insurrections as are illustrated by the uprising of the canker-worms in Mr. Robison's orchard?

Three facts stand out very clearly as results of these investigations: 1. Birds of the most varied character and habits, migrant and resident, of all sizes, from the tiny wren to the bluejay, birds of the forest, garden and meadow, those of arboreal and those of terrestrial habit, were certainly either attracted or detained here by the bountiful supply of insect food, and were feeding freely upon the species most abundant. That thirty-five

per cent. of the food of all the birds congregated in this orchard should have consisted of a single species of insect, is a fact so extraordinary that its meaning can not be mistaken. Whatever power the birds of this vicinity possessed as checks upon destructive irruptions of insect life, was being largely exerted here to restore the broken balance of organic nature. And while looking for their influence over one insect outbreak we stumbled upon at least two others, less marked, perhaps incipient, but evident enough to express themselves clearly in the changed food ratios of the birds.

2. The comparisons made show plainly that the reflex effect of this concentration on two or three unusually numerous insects was so widely distributed over the ordinary elements of their food that no especial chance was given for the rise of new fluctuations among the species commonly eaten. That is to say, the abnormal pressure put upon the canker-worm and vine chafer was compensated by a general diminution of the ratios of all the other elements, and not by a neglect of one or two alone. If the latter had been the case, the criticism might easily have been made that the birds, in helping to reduce one oscillation, were setting others on foot.

3. The fact that, with the exception of the indigo bird, the species whose records in the orchard were compared with those made elsewhere, had eaten in the former situation as many caterpillars other than canker-worms as usual, simply adding their canker-worm ratios to those of other caterpillars, goes to show that these insects are favorites with a majority of birds.

TABLES OF THE FOOD.

	Turdidæ.				Sialidæ.	Paridæ.	Troglodytidæ.	Mniotiltidæ.						
	Robin.	Catbird.	Brown Thrush.	Total.	Bluebird.	Black-capped Chickadee.	House Wren.	Tennessee Warbler.	Summer Yellow Bird.	Chestnut-sided Warbler.	Black-poll Warbler.	Black-throated Green Warbler.	Maryland Yellow-throat.	Total.
Number of Birds	9	14	4	27	5	2	5	1	5	2	4	1	2	15
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
	9	14	4	27	5	2	5	1	5	2	4	1	2	15
Animal Food	1.00	1.00	1.00	1.00	1.00	1.00	1 00	1.00	1.00	1.00	.95	1 00	1.00	.99
	3			3										
I. MOLLUSCA	.01	....	....	+	....	....	....	....	....	....	....	....	....	....
	9	14	4	27	5	2	5	1	5	2	4	1	2	15
II. INSECTA	.93	.98	.94	.96	.98	1.00	.91	1.00	.94	1.00	.95	1.00	1.00	.97
	4	11	2	17			2		2	2	3	1		8
1. *Hymenoptera*	.01	.14	.03	.08	....	....	.05	...	.02	07	.04	.02	...	.03
	4	11	2	17			2			2	3			5
Formicidæ	.01	.14	.03	.08	....	....	.05	....	....	.06	.04	....	....	.02
	9	12	4	25	3	2	5	1	5	2	4	1	2	15
2. *Lepidoptera*	.54	.26	.22	.34	.17	.61	.39	.80	.67	.75	.66	.70	.82	.71
	6	5	1	12										
Noctuidæ (larvæ)	.28	.04	.05	.12	....	....	....	....	....	....	....	....	....	....
Nephelodes violans (larvæ)	3 .14	1 .01	....	4 .05	....	....	....	....	....	....	....	....	....	....
	3	8	2	13	1	2	3	1	5	2	4	1	1	14
Anisopteryx vernata	.21	.15	.12	.16	.12	.61	.46	.80	.67	.65	.66	.70	.37	.64
							3		1	2	4	1	2	10
3. *Diptera*	....	....	....	....	....	....	.04	....	.01	.02	.05	.05	.04	.03
							2			1	4	1	2	8
Gnats	....	....	....	....	....	....	.03	....	....	.02	.05	.05	.04	.03
	9	14	4	27	5	2	5	1	5	2	4	1	1	14
4. *Coleoptera*	.36	.56	.67	.51	.66	.39	.13	.20	.23	.11	.19	.08	.08	.18
	4	5	3	12	3		1		1		1			2
Carabidæ	.01	.04	.12	.04	.23	....	.01	....	.01	....	.01	....	....	.01
	1			1									1	1
Staphylinidæ	.04	....	....	.01	....	....	....	....	....	....	....	....	.05	.01
							1							
Phalacridæ	....	....	....	....	....	....	+	....	....	....	....	....	....	....
	5	2	1	8										
Histeridæ	.01	+	.02	.01	....	....	....	....	....	....	....	....	....	....
	6	12	3	21	5		1		1	1	1			3
Scarabæidæ	.18	.49	.44	.38	.36	....	.01	....	.06	.05	.02	....	....	.03
	3	10	2	15	4									
Anomala binotata	.14	.36	.14	.25	.36	....	....	....	....	....	....	....	....	....
	6	1	3	10			1							
Elateridæ	.11	.01	.06	.05	....	....	.01	....	....	....	....	....	....	....
								1	1					2
Lampyridæ	....	....	....	....	....	....	....	.20	.04	....	....	....	....	.03
						1	2		3	2	3	1	1	10
Cerambycidæ	....	....	....	....	....	.25	.04	....	.12	.06	.15	.15	.03	.10
Psenocerus supernotatus	....	....	....	....	....	....	....	....	3 .12	2 .06	3 .15	1 .15	1 .03	10 .10
					1									
Chrysomelidæ	....	....	....	....	.05	....	....	....	....	....	....	....	....	....
	3	3	1	7		1	1		1					1
Rhynchophora	.01	.01	.03	.02	....	.10	.01	....	+	....	....	....	....	+
	3	6		9	3		4		2	1	1	1	2	7
5. *Hemiptera*	.02	.02	....	.02	.15	....	.10	....	.01	.05	.01	.05	.06	.02

TABLES OF THE FOOD—Continued.

	Robin.	Catbird.	Brown Thrush.	Total.	Bluebird.	Black-capped Chickadee.	House Wren.	Tennessee Warbler.	Summer Yellow Bird.	Chestnut-sided Warbler.	Black-poll Warbler.	Black-throated Green Warbler.	Maryland Yellow-throat.	Total.
Number of Birds	9	14	4	27	5	2	5	1	5	2	4	1	2	15
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
Homoptera							1 .02			1 .05				
Aphides										1 .05				
Tettigonidæ							1 .02							
Heteroptera	3 .02	4 .02		6 .02	3 .15		1 .06						1 .05	1 †
Aradidæ							1 .02							
Lygæidæ							1 .02						1 .05	1 †
Chinchbugs							1 .02							
Coreidæ	1 .01			1 .01										
Cydnidæ	2 .01	3 .02		5 .01	3 .15									
III. ARACHNIDA					2 .02		3 .06		3 .06		1 †	1 †	5 .02	
IV. MYRIAPODA	2 .05	2 .02	1 .06	5 .03			1 .01							
VI. VERMES (Lumbricus)	1 .01			1 .01										
Vegetable Food (seeds)											1 .05		1 .01	

TABLES OF THE FOOD—Continued.

	Vireonidæ.	Ampelidæ.	Hirundinidæ	Fringillidæ.								Icteridæ.		
	Warbling Vireo.	Cedar Wax-wing.	Cliff Swallow.	American Gold-finch.	Yellow-winged Sparrow.	Chipping Sparrow	Field Sparrow.	Black-throated Bunting.	Rose-breasted Grosbeak.	Indigo Bird.	Total.	Cowbird.	Red-winged Blackbird.	Baltimore Oriole.
Number of Birds.....	3	7	1	1	1	8	3	14	2	18	47	1	2	3
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
Animal Food.....	3 1.00	7 1.00	1 1.00	1 .30	1 .65	8 .96	3 1.00	14 .94	2 .80	18 .97	47 .93	1 .30	2 .50	3 1.00
I. MOLLUSCA.....	....	....	....	....	....	....	....	1 .06	....	....	1 .01	....	....	....
II. INSECTA.....	3 1.00	7 1.00	1 1.00	1 .30	1 .35	8 .95	3 1.00	14 .88	2 .80	18 .97	47 .91	1 .30	2 .50	3 1.00
1. *Hymenoptera*.....	....	1 †	1 .02	....	....	3 .03	....	3 .01	1 .02	2 .01	8 .01	....	....	....
Formicidæ.....	....	....	....	....	....	1 .01	....	1 †	....	....	2 †	....	....	....
Tenthredinidæ....	....	....	....	....	....	1 .02	....	....	....	....	1 .01	....	....	....
2. *Lepidoptera*.....	3 .79	7 1.00	....	....	1 .30	7 .32	3 .47	13 .65	2 .63	17 .67	43 .57	....	2 .29	3 .40
Noctuidæ.....	....	....	....	....	....	....	....	2 .14	....	....	2 .04	....	1 .25	....
Nephelodes violans (larvæ)...	....	....	....	....	....	....	....	....	....	....	....	....	1 .25	....
Phalænidæ (larvæ)	3 .44	7 1.00	....	....	....	2 .16	1 .20	10 .46	1 .05	17 .60	31 .41	....	1 .01	3 .40
Anisopteryx vernata.....	3 .44	7 1.00	....	....	....	2 .16	1 .20	10 .43	1 .05	17 .59	31 .40	....	1 .01	3 .40
3. *Diptera*.....	1 .03	....	....	....	....	7 .28	1 .05	....	....	....	8 .05	....	....	....
Gnats.....	....	....	....	....	....	7 .28	1 .05	....	....	....	8 .05	....	....	....
Muscidæ.....	1 03	....	....	....	....	....	....	....	....	....	....	....	....	....
4. *Coleoptera*.....	2 .15	3 †	1 .98	1 .30	1 .05	7 .25	3 .47	11 .22	2 .15	18 .29	43 .26	1 .30	2 .11	2 .60
Carabidæ.....	2 .05	....	....	1 .30	....	....	....	3 .04	....	....	4 .02	....	....	....
Nitidulidæ.....	....	....	....	....	....	....	....	1 .01	....	....	1 †	....	....	....
Histeridæ.....	....	....	....	....	....	....	1 .03	3 .04	....	1 .01	5 .01	....	....	....
Trogositidæ.....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 .01
Scarabæidæ.....	1 .08	3 †	1 .98	....	....	3 .14	3 .08	7 .11	1 .02	9 .15	23 .12	1 .25	1 .03	3 .50
Anomala binotata	1 .08	....	....	....	....	2 .09	....	2 .04	1 .02	4 .10	9 .06	....	1 .03	3 .50
Elateridæ.....	....	....	....	..	....	...	1 .01	....	....	2 .01	3 .01	....	1 .04	1 .01
Lampyridæ.....	....	....	....	....	....	....	....	....	1 †	....	1 †	....	....	....
Cerambycidæ.....	1 .02	....	....	....	....	....	....	....	....	....	....	....	....	3 .06
Psenocerus supernotatus.....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 .02
Chrysomelidæ.....	....	....	....	....	....	2 .01	....	....	....	....	2 †	1 .02	....	....

TABLES OF THE FOOD — Continued.

	Warbling Vireo.	Cedar Wax-wing.	Cliff Swallow.	American Goldfinch.	Yellow-winged Sparrow.	Chipping Sparrow	Field Sparrow.	Black-throated Bunting.	Rose-breasted Grosbeak.	Indigo Bird.	Total.	Cowbird.	Red-winged Blackbird.	Baltimore Oriole.
Number of Birds	3	7	1	1	1	8	3	14	2	18	47	1	2	3
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
Rhynchophora	....	....	....	....	....	1 .01	3 .08	6 .02	2 .08	6 .03	18 .03	....	1 .04	1 .02
5. *Hemiptera*	1 .03	....	....	....	....	5 .06	1 .01	....	....	1 †	7 .01	....	1 †	....
Homoptera	....	....	....	....	....	....	....	....	....	1 †	1 †	....	1 †	....
Heteroptera	....	....	....	....	....	1 .03	....	....	....	....	1 †	....	....	....
Lygæidæ	....	....	....	....	....	1 .03	....	....	....	....	1 .01	....	....	....
Cydnidæ	1 .03	....	....	....	....	....	....	....	....	....	....	....	....	....
6. *Orthoptera* (Acrididæ)	....	....	....	....	....	....	....	....	....	....	....	....	1 .10	....
III. ARACHNIDA	....	....	....	....	1 .30	6 .01	2 †	....	....	....	9 .01	....	....	....
Vegetable Food (seeds)	....	....	....	1 70	1 .35	4 .04	....	3 .06	2 .20	6 .03	17 .07	1 .70	2 .50	....
Compositæ	....	....	....	....	....	....	....	....	....	2 .01	2 .01	....	....	....
Polygonum	....	....	....	....	....	....	....	....	....	....	....	1 .05	1 05	....
Wheat	....	....	....	....	....	....	....	1 .05	....	....	1 .02	....	1 .45	....
Setaria	....	....	....	....	1 .15	2 .01	....	2 †	....	2 .01	7 .01	....	....	....
Corn	....	....	....	....	....	....	....	....	....	....	....	1 .60	....	....
Panicum	....	....	....	....	....	1 .01	....	....	....	....	1 †	....	....	....

TABLES OF THE FOOD — Continued.

	Icteridæ			Tyrannidæ.					Cuculidæ.	Picidæ.			Columbidæ.	Perdicidæ.
	Orchard Oriole.	Bronzed Grackle.	Total.	King Bird.	Wood Pewee.	Traill's Flycatcher	Yellow-bellied Flycatcher.	Total.	Black-billed Cuckoo.	Red-headed Woodpecker.	Flicker.	Total.	Mourning Dove.	Quail.
Number of Birds	2	3	11	3	3	2	1	9	1	4	1	5	1	2
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
	2	3	11	3	3	2	1	9	1	4	1	5		2
Animal Food	1 00	.38	.68	1.00	1.00	1 00	1.00	1.00	1 00	.80	1.00	.84	....	.04
	2	3	11	3	3	2	1	9	1	4	1	5		2
II. INSECTA	1.00	.30	.66	1 00	1.00	1.00	1.00	1.00	1.00	.80	1.00	.84	....	.04
	1		1	1	2	2	1	6		1	1	2		
1. *Hymenoptera*	.03	....	.01	.05	.12	.48	.02	.16	....	.01	1.00	.21	....	....
	1		1		1	1		2		1	1	2		
Formicidæ	.03	....	.01	....	.04	.05	....	.02	....	.01	1.00	.21	....	....
						1		1						
Ichneumonidæ	....	....	....	....	....	.33	....	.07	....	....	....	....	....	....
	2		7	2	1	1	1	5	1	1		1		
2. *Lepidoptera*	.97	....	.34	.28	.05	.25	.30	.20	.95	.15	....	.12	....	....
			1											
Noctuidæ (larvæ)	....	....	.05	....	....	....	....	....	....	....	....	....	....	....
Nephelodes violans (larvæ)	....	....	1 .05	....	....	....	....	....	....	....	....	....	....	....
	2		6	2		1		3	1	1		1		
Phalænidæ (larvæ)	.77	....	.25	.28	....	.25	....	.15	.75	.15	....	.12	....	....
	2		6	2		1		3	1	1		1		
Anisopteryx vernata	.77	....	.25	.28	....	.25	....	.15	.75	.15	....	.12	....	....
					3		1	4						
3. *Diptera*	....	....	....	....	.55	....	.08	.19	....	....	....	....	....	....
							1	1						
Tipulidæ	....	....	....	....	....	....	.08	.01	....	....	....	....	....	....
					1			1						
Gnats	....	....	....	....	.23	....	....	.08	....	....	....	....	....	....
					2			2						
Muscidæ	....	....	....	....	.32	....	....	.10	....	....	....	....	....	....
		3	8	3	2	2	1	8	1	4		4		2
4. *Coleoptera*	....	.30	.29	.67	.28	.25	.50	.43	.05	.64	....	.51	....	.04
		3	3							2		2		1
Carabidæ	....	.16	.04	....	....	....	....	....	....	.24	....	.19	....	.01
					1			1						
Nitidulidæ	....	....	....	....	.10	....	....	.03	....	....	....	....	....	....
			1											
Trogositidæ	....	....	†	....	....	....	....	....	....	....	....	....	....	....
		1	1											
Lucanidæ	....	.08	.02	....	....	....	....	....	....	....	....	....	....	....
		1	6	3	2	2	1	8	1	3		3		
Scarabæidæ	....	.01	.17	.58	.18	.10	.40	.33	.05	.29	....	.23	....	....
			4	2			1	3		2		2		
Anomala binotata	....	....	.14	.43	....	....	.25	.17	....	.04	....	.03	....	....
		1	3	1				1		2		2		
Elateridæ	....	.05	.03	.07	....	....	....	.02	....	.09	....	.07	....	....
				1				1						
Lampyridæ	....	....	....	.02	....	....	....	.01	....	....	....	....	....	....
			3				1	1						
Cerambycidæ	....	....	.02	....	....	....	.10	.01	....	....	....	....	....	....
Psenocerus supernotatus	....	....	1 .01	....	....	....	1 .10	1 .01	....	....	....	....	....	....
			1											1
Chrysomelidæ	....	....	†	....	....	....	....	....	....	....	....	....	....	.02

TABLES OF THE FOOD — Concluded.

	Orchard Oriole.	Bronzed Grackle.	Total.	King Bird.	Wood Pewee.	Traill's Flycatcher.	Yellow-bellied Flycatcher.	Total.	Black-billed Cuckoo.	Red-headed Woodpecker.	Flicker.	Total.	Mourning Dove.	Quail.
Number of Birds.....	2	3	11	3	3	2	1	9	1	4	1	5	1	2
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.													
Rhynchophora	....	1 †	3 .01	....	....	....	....	....	....	....	....	....	...	1 .01
5. *Hemiptera*.....	....	....	1 †	...	....	....	1 .10	1 .01	....	....	....	....	...	....
Homoptera.....	....	....	1 †	....	....	....	....	....	....	....	....	....	....	....
Cydnidæ.....	....	....	....	....	....	....	1 .10	1 .01	....	....	....	....	....	....
6. *Orthoptera* (Acrididæ).....	....	....	1 .02	....	....	....	....	....	....	....	....	....	....	....
V. CRUSTACEA (Crawfish).....	....	1 .08	1 .02	....	....	....	....	....	....	....	....	....	....	....
Vegetable Food (Seeds)	....	3 .62	6 .32	....	....	....	....	....	....	2 .20	2 .16	....	1 1.00	2 .96
Leguminosæ.....	....	....	....	....	....	....	....	....	....	....	....	....	1 .25	1 .02
Compositæ.....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 .32
Polygonum.....	....	....	2 .01	....	....	....	....	....	....	....	....	....	....	2 .03
Wheat.....	....	....	1 .08	....	....	....	....	....	....	....	....	....	....	....
Setaria.....	....	....	....	....	....	....	....	....	....	....	....	....	....	1 .02
Corn.....	....	3 .62	4 22	....	....	....	....	....	....	2 .20	2 .16	....	1 .75	2 .57

GENERA AND SPECIES RECOGNIZED IN THE FOOD.

The following lists are intended to supplement the preceding tables and, taken together with them, to present all the details concerning the food of the birds observed in the orchard, upon which the foregoing discussion is based. In the first list the genera and species recognized in the food of each kind of bird are given separately ; in the second the food elements are systematically arranged, and against the name of each element the names of all the species of birds are placed in whose food that element was recognized. The figures preceding the names of the birds in the second list indicate the number of individuals in which the given element was found :

TURDIDÆ.

Turdus migratorius · Helix, Hyalina, Limnea humilis, Formica, Nephelodes violans, Anisopteryx vernata, Elaphrus ruscarius, Staphylinus badipes, Aphodius, A. inquinatus, Phyllo-

phaga, Anomala lucicola, A. binotata, Melanotus, Monocrepidius, Graphorhinus vadosus, Alydus eurinus, Cœnus delius, Hymenarcys, Polydesmus serratus, Lumbricus.

Mimus carolinensis: Formica, F. fusca, Lasius, L. niger, Nephelodes violans, Anisopteryx vernata, Clivina striatopunctata, Anisodactylus, Hister americanus, H. perplexus, Onthophagus, Aphodius, A. inquinatus, Phyllophaga, Anomala binotata, Melanotus, Graphorhinus vadosus, Tanymecus confertus, Baris, Sphenophorus, Cœnus delius, Podisus spinosus, Iulus.

Harporhynchus rufus: Anisopteryx vernata, Chlænius, Stenolophus conjunctus, Hister americanus, H. perplexus, Aphodius, Diplotaxis georgiæ, Anomala binotata, Melanotus, Monocrepidius, Baris confinis, Iulus.

SAXICOLIDÆ.

Sialia sialis: Anisopteryx vernata, Anisodactylus baltimorensis, Aphodius, Anomala binotata, Chrysomela suturalis, Diabrotica vittata, Cœnus delius, Hymenarcys æqualis, Euschistus.

PARIDÆ.

Parus atricapillus: Anisopteryx vernata, Psenocerus supernotatus.

TROGLODYTIDÆ.

Troglodytes domesticus: Anisopteryx vernata, Olibrus, Aphodius, Monocrepidius auritus, Psenocerus supernotatus, Blissus leucopterus, Iulus.

MNIOTILTIDÆ.

Helminthophaga peregrina: Anisopteryx vernata, Telephorus bilineatus.

Dendrœca æstiva: Anisopteryx vernata, Aphodius, Telephorus bilineatus, Psenocerus supernotatus.

Dendrœca pennsylvanica: Anisopteryx vernata, Psenocerus supernotatus.

Dendrœca striata: Anisopteryx vernata, Aphodius, Psenocerus supernotatus.

Dendrœca virens: Anisopteryx vernata, Psenocerus supernotatus.

Geothlypis trichas: Anisopteryx vernata, Psenocerus supernotatus, Piesma cinerea.

VIREONIDÆ.

Vireo gilvus: Anisopteryx vernata, Anomala binotata, Telephorus bilineatus, Euschistus.

AMPELIDÆ.

Ampelis cedrorum: Anisopteryx vernata, Aphodius inquinatus, A. femoralis.

HIRUNDINIDÆ.

Petrochelidon lunifrons: Aphodius inquinatus.

FRINGILLIDÆ.

Coturniculus passerinus: Setaria.

Spizella domestica: Anisopteryx vernata, Anomala binotata, Baris, Setaria, Panicum.

Spizella agrestis: Anisopteryx vernata, Onthophagus, Aphodius A. inquinatus, Monocrepidius, Baris, Sphenophorus.

Spiza americana: Helix, Agapestemon, Anisopteryx vernata, Anisodactylus, Ips fasciatus, Aphodius, A. inquinatus, Anomala binotata, Sphenophorus, Wheat, Setaria.

Zamelodia ludoviciana: Anisopteryx vernata, Anomala binotata.

Passerina cyanea: Aphidius, Anisopteryx vernata, Onthophagus, Aphodius, Anomala binotata, Monocrepidius, Baris, Setaria.

ICTERIDÆ.

Molothrus ater: Aphodius, Dibolia aërea, Polygonum, Corn.

Agelæus phœniceus: Nephelodes violans, Anisopteryx vernata, Anomala binotata, Tanymecus confertus, Polygonum, Wheat.

Icterus galbula: Anisopteryx vernata, Anomala binotata, Phymatodes variabilis, Psenocerus supernotatus.

Icterus spurius: Camponotus, Anisopteryx vernata.

Quiscalus purpureus æneus: Calosoma calidum, Dorcus parallelus, Crawfish, Corn.

TYRANNIDÆ.

Tyrannus carolinensis: Anisopteryx vernata, Aphodius inquinatus, Anomala, A. binotata, Melanotus.

Contopus virens: Ips fasciatus, Aphodius, A. inquinatus.

Empidonax trailli: Anisopteryx vernata, Anomala.

Empidonax flaviventris: Aphodius, Anomala binotata, Psenocerus supernotatus, Hymenarcys.

CUCULIDÆ.

Coccyzus erythrophthalmus: Anisopteryx vernata, Anomala.

PICIDÆ.

Melanerpes erythrocephalus: Camponotus, Anisopteryx vernata, Calosoma calidum, Scarites substriatus, Canthon hudsonias, Anomala binotata, Melanotus, Corn.

COLUMBIDÆ.

Zenaidura carolinensis: Corn.

PERDICIDÆ.

Ortyx virginiana: Chrysomela suturalis, Polygonum, Setaria, Corn.

Helix: 1 Turdus migratorius, 1 Spiza americana.

Hyalina: 1 Turdus migratorius.

Limnæa humilis: 1 Turdus migratorius.

Agapestemon: 1 Spiza americana.

Formica sp.: 1 Turdus migratorius, 1 Mimus carolinensis.

F. fusca: 1 Mimus carolinensis.

Lasius sp.: 1 Mimus carolinensis.

L. niger: 3 Mimus carolinensis.

Camponotus: 1 Icterus spurius, 1 Melanerpes erythrocephalus.

Aphidius: 1 Passerina cyanea.

Nephelodes violans: 3 Turdus migratorius, 1 Mimus carolinensis, 1 Agelæus phœniceus.

Anisopteryx vernata: 3 Turdus migratorius, 8 Mimus carolinensis, 2 Harporhynchus rufus, 1 Sialia sialis, 2 Parus atricapillus, 3 Troglodytes domesticus, 1 Helminthophaga peregrina, 5 Dendrœca æstiva, 2 Dendrœca pennsylvanica, 4 Dendrœca striata, 1 Dendrœca virens, 1 Geothlypis trichas, 3 Vireo gilvus, 7 Ampelis cedrorum, 2 Spizella domestica, 1 Spizella agrestis, 10 Spiza americana, 1 Zamelodia ludoviciana, 17 Passerina cyanea, 1 Agelæus phœniceus, 3 Icterus galbula, 2 Icterus spurius, 2 Tyrannus carolinensis, 1 Empidonax trailli, 1 Coccyzus erythrophthalmus, 1 Melanerpes erythrocephalus.

Elaphrus ruscarius: 1 Turdus migratorius.

Clivina striatopunctata: 1 Mimus carolinensis.

Calosoma calidum: 1 Quiscalus purpureus æneus, 1 Melanerpes erythrocephalus.

Scarites substriatus: 1 Melanerpes erythrocephalus.

Chlœnius: 1 Harporhynchus rufus.

Anisodactylus sp.: 1 Mimus carolinensis, 1 Spiza americana.

A. baltimorensis: 2 Sialia sialis.

Stenolophus conjunctus: 1 Harporhynchus rufus.

Staphylinus badipes: 1 Turdus migratorius.

Ips fasciatus: 1 Spiza americana, 1 Contopus virens.

Olibrus: 1 Troglodytes domesticus.

Hister americanus: 1 Mimus carolinensis, 1 Harporhynchus rufus.

H. perplexus: 1 Mimus carolinensis, 1 Harporhynchus rufus.

Dorcus parallelus: 1 Quiscalus purpureus æneus.

Canthon hudsonias: 1 Melanerpes erythrocephalus.

Onthophagus: 1 Mimus carolinensis, 1 Spizella agrestis, 1 Passerina cyanea.

Aphodius sp.: 1 Turdus migratorius, 1 Mimus carolinensis, 1 Harporhynchus rufus, 1 Sialia sialis, 1 Troglodytes domesticus, 1 Dendrœca æstiva, 1 Dendrœca striata, 1 Spizella agrestis, 3 Spiza americana, 1 Passerina cyanea, 1 Molothrus ater, 2 Contopus virens, 1 Empidonax flaviventris.

A. inquinatus: 1 Turdus migratorius, 1 Mimus carolinensis, 2 Ampelis cedrorum, 1 Petrochelidon lunifrons, 1 Spizella agrestis, 1 Spiza americana, 1 Tyrannus carolinensis, 1 Contopus virens.

A. femoralis: 1 Ampelis cedrorum.

Diplotaxis georgiæ: 1 Harporhynchus rufus.

Phyllophaga: 1 Turdus migratorius, 3 Mimus carolinensis.

Anomala sp.: 1 Tyrannus carolinensis, 2 Empidonax trailli, 1 Coccyzus erythrophthalmus.

A. lucicola: 1 Turdus migratorius.

A. binotata: 3 Turdus migratorius, 10 Mimus carolinensis, 2 Harporhynchus rufus, 4 Sialia sialis, 1 Vireo gilvus, 2 Spizella domestica, 2 Spiza americana, 1 Zamelodia ludoviciana, 4 Passerina cyanea, 1 Agelæus phœniceus, 3 Icterus galbula, 2 Tyrannus carolinensis, 1 Empidonax flaviventris, 2 Melanerpes erythrocephalus.

Melanotus: 1 Turdus migratorius, 1 Mimus carolinensis, 1 Harporhynchus rufus, 1 Tyrannus carolinensis, 1 Melanerpes erythrocephalus.

Monocrepidius: 1 Turdus migratorius, 1 Harporhynchus rufus, 1 Spizella agrestis, 1 Passerina cyanea.

M. auritus: 1 Troglodytes domesticus.

Telephorus bilineatus: 1 Helminthophaga peregrina, 1 Dendrœca æstiva, 1 Vireo gilvus.

Phymatodes variabilis: 1 Icterus galbula.

Psenocerus supernotatus: 1 Parus atricapillus, 2 Troglodytes domesticus, 3 Dendrœca æstiva, 2 Dendrœca pennsylvanica, 3 Dendrœca striata, 1 Dendrœca virens, 1 Geothlypis trichas, 1 Icterus galbula, 1 Empidonax flaviventris.

Chrysomela suturalis: 1 Sialia sialis, 1 Ortyx virginiana.

Diabrotica vittata: 1 Sialia sialis.

Dibolia aërea: 1 Molothrus ater.

Graphorhinus vadosus: 1 Turdus migratorius, 1 Mimus carolinensis.

Tanymecus confertus: 1 Mimus carolinensis, 1 Agelæus phœniceus.

Baris: 1 Mimus carolinensis, 1 Spizella domestica, 1 Spizella agrestis, 1 Passerina cyanea.

B. confinis : 1 Harporhynchus rufus.

Sphenophorus : 1 Mimus carolinensis, 1 Spizella agrestis, 1 Spiza americana.

Piesma cinerea : 1 Geothlypis trichas.

Blissus leucopterus : 1 Troglodytes domesticus.

Alydus eurinus : 1 Turdus migratorius.

Cœnus delius : 1 Turdus migratorius, 1 Mimus carolinensis, 1 Sialia sialis.

Hymenarcys : 1 Turdus migratorius, 1 Empidonax flaviventris.

H. æqualis : 2 Sialia sialis.

Euschistus : 1 Sialia sialis, 1 Vireo gilvus.

Podisus spinosus : 1 Mimus carolinensis.

Polydesmus serratus : 1 Turdus migratorius.

Iulus : 1 Mimus carolinensis, 1 Harporhynchus rufus, 1 Troglodytes domesticus.

Crawfish : 1 Quiscalus purpureus æneus.

Lumbricus : 1 Turdus migratorius.

Polygonum : 1 Molothrus ater, 1 Agelæus phœniceus, 2 Ortyx virginiana.

Wheat : 1 Spiza americana, 1 Agelæus phœniceus.

Setaria : 1 Coturniculus passerinus, 2 Spizella domestica, 1 Spiza americana, 1 Passerina cyanea, 1 Ortyx virginiana.

Corn : 1 Molothrus ater, 3 Quiscalus purpureus æneus, 2 Melanerpes erythrocephalus, 1 Zenaidura carolinensis, 2 Ortyx virginiana.

Panicum : 1 Spizella domestica.

THE FOOD RELATIONS OF THE CARABIDÆ AND COCCINELLIDÆ.

By S. A. FORBES.

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

**Notes on Insectivorous Coleoptera.* By S. A. Forbes. Illinois State Laboratory of Natural History, Bulletin No. 3, pp. 153–160.

†Pp. 149–152.

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.

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*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 Sphæronemei, 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 Evarthrus.

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 Chlænius, 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, Chlænius 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 cornfield 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, gramineaceous 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 AMD 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. partiarius: 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 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.

KINDS OF FOOD.	Calosoma.	Scarites.	Brachynus.	Galerita.	Lebia.	Calathus.	Platynus.	Evarthrus.	Pterostichus.	Amara.	Dicælus.	Chlænius.	Cratacanthus.	Agonoderus.	Anisodactylus.	Amphasia.	Bradycellus.	Harpalus.	Patrobus.	Summary.
No. of Specimens.....	1	2	1	4	3	3	2	5	7	4	2	6	1	4	19	4	1	12	2	83
	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	43
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
		1		4	1	2	1	5	4			5			2	1	1	2	1	30
I. INSECTA.....	....	.50	....	.88	.11	.65	.17	.90	.43	...	....	.67	...	...	.03	.03	1.00	.03	.33	.26
						1		1				1								3
Larvæ.....	...	....	....	...	...	.32	...	.10	...	...	....	.08	...	...	...	...	...	...	...	.02
									1									1		2
1. *Hymenoptera*	....	...	....	...	...	..	..	.	.13	...	....	...	...	...	...	...	...	.01	...	.01
																		1		1
Formicidæ	...	....	....	...	...	...	...	...	...	...	....	...	...	...	...	...	...	.01	...	†
				3		1		1				1						1	1	8
2. *Lepidoptera* (larvæ).	....	....	....	.63	...	.33	..	.20	...	...	....	.17	...	...	...	...	...	.02	.30	.08
																		1		1
3. *Diptera*.....	....	....	....	...	...	...	...	..	...	...	...	...	...	...	...	...	...	†	...	†
								2												2
4. *Coleoptera*	....	....	....	...	...	...	...	.39	...	...	....	...	...	...	...	...	...	...	...	.02
								1												1
Larvæ.....	....	....	....	...	...	...	...	.19	...	...	....	...	...	...	...	...	...	...	...	.01
								1			....									1
Scarabæidæ.....	....	....	....	...	...	...	...	20	...	...		...	...	...	...	...	...	...	...	.01
							1												1	2
5. *Hemiptera*(Aphides)	....	....	....	...	...	...	.17	...	...	...	....	...	...	...	...	...	...	...	.03	.01
II. ARACHNIDA (Mites)...	....	....	....	...	...	...	...	...	1 .01	1 .22	...	...	...	1 .01	...	...	...	2 .01	...	5 .01
III. VERMES (Lumbricus)..	....	....	....	...	...	...	...	...	...	...	....	1 .08	...	...	...	...	...	...	...	1 .01
				2	3	2	2	1	4	4		2	1	4	15	4		12	2	58
VEGETABLE FOOD	....	....	....	.12	.56	.35	.83	.10	.27	.78	..	25	1.00	.99	.76	.97	...	.93	.67	.58
														2	3	1		1	1	8
Seeds	....	....	....	...	...	...	...	...	...	...	....	...	...	48	.16	.22	....	.08	.50	.10
							1		2	1		1						3		8
1. *Exogens*.....	....	....	....	...	...	...	.50	..	.14	.25	...	.08	...	...	...	...	...	.17	...	.07
									1											1
Seeds.....	....	....	....	...	...	...	...	...	†	...	....	...	...	...	...	...	...	...	...	†
																		3		3
Compositæ (Pollen)...	....	....	....	...	...	...	...	...	...	...	....	...	...	...	...	...	...	.17	...	.03
																		2		2
Ambrosia	...	...	..	...	...	...	...	...	...	...	....	...	...	...	...	...	...	17	...	.03
				1	1	2	1	1		1				1	7			4	1	20
2. *Endogens*	....	....	....	.10	.11	.35	.30	.10	...	.28	...	...	...	.25	.34	...	...	.23	.10	.17
				1	1	2	1			1				1	7			4	1	18
Gramineæ.....	....	....	....	.10	.11	.35	.30	...	...	.28	....	...	...	.25	.34	...	...	.23	.10	.17
							1			1					1			1		4
Seeds.....	....	....	....	...	...	...	.30	...	...	*	....	...	...	...	.05	...	...	†	...	.02
					1	2														4
Pollen.....	....	....	....	...	.11	.35	...	...	...	...	...	...	...	...	...	...	...	...	...	.02
														1	4					5
Phleum (seeds)	...	....	....	...	...	...	...	...	...	...	....	...	...	.25	.21	...	...	.	...	.06
															2					2
3. *Hepaticæ*.....	....	....	....	...	...	...	...	...	...	...	....	...	...	...	.01	...	...	...	...	†
								1				1								2
4. *Algæ*.....	....	....	....	...	...	...	...	†	...	...	....	†	...	...	...	...	...	...	...	†
												1								1
Protococcus	....	....	....	...	...	...	...	...	...	...	....	†	...	...	...	...	...	...	...	†
				1	3		1	1	3	1		1	1	2	3			5	1	23
5. *Fungi*.....	....	....	....	†	.45	...	.03	†	.07	.21	....	.14	1.00	.11	.04	...	...	.13	.07	.09
												1								1
Coprinus.....	....	....	....	...	...	...	...	...	...	...	....	.14	...	...	...	...	...	...	...	.01
					2															1
Phoma	....	....	....	...	.45	...	...	...	...	...	....	...	...	...	...	...	...	...	...	.02
															1					1
Coleosporium	....	....	....	...	...	...	...	...	...	...	....	...	...	...	†	...	...	...	...	†
												1								1
Dematiei.....	....	....	..	...	...	...	...	...	...	...	....	†	...	...	...	...	...	...	...	†
					2				1				1					2		6
Helminthosporium....	....	....	....	...	†	...	...	...	†	...	....	...	1.00	...	...	...	...	†	...	.01
														1	1					2
Cladosporium	....	...	....	...	...	...	...	...	...	...	...	...	...	.01	.01	...	...	...	...	†
										1					1			1		3
Peronospora	....	...	....	...	...	...	...	...	...	.19	....	...	...	...	†	...	...	.03	...	.01
														1						1
Ramularia	....	....	....	...	...	...	...	...	...	...	....	...	...	.10	...	...	...	...	...	.01

CARABIDÆ AND CANKER-WORMS.

	Calosoma.	Pasimachus.	Scarites.	Galerita.	Calathus.	Platynus.	Evarthrus.	Pterostichus.	Amara.	Dicælus.	Chlænius.	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 1.00	2 1.00	4 1.00	13 .94	3 .68	1 1.00	2 1.00	3 .80	..	1 1.00	16 .92	1 .09	1 .25	2 .35	59 .77
I. MOLLUSCA	....	....	....	....	....	....	....	....	....	1 1.00	....	....	....	....	1 .02
II. INSECTA	5 .50	....	2 .50	13 .85	3 .68	....	2 1.00	1 .13	....	....	12 .64	1 .09	1 .25	2 .35	42 .50
Larvæ	....	....	....	2 .11	....	....	....	....	....	....	1 .06	....	....	....	3 .04
1. *Hymenoptera* (ants)	....	....	....	....	....	....	1 .05	....	....	....	....	....	....	....	1 †
2. *Lepidoptera* (larvæ)	....	....	....	8 .56	1 .33	....	2 .90	1 .11	....	....	8 .41	....	....	1 .33	21 .26
Anisopteryx vernata	....	....	....	7 .52	1 .33	....	2 .90	....	....	....	5 .26	....	....	1 .33	16 .21
Noctuidæ	....	....	....	1 .01	....	....	....	....	....	....	2 .12	....	....	....	3 .03
3. *Diptera*	....	....	....	3 .07	1 .02	....	1 .05	....	....	....	1 .01	1 .09	....	....	7 .03
Culicidæ	....	....	....	....	....	....	1 .05	....	....	....	....	....	....	....	1 †
4. *Coleoptera*	....	....	....	....	....	....	....	....	....	....	1 .06	....	....	....	1 .01
Telephoridæ	....	....	....	....	....	....	....	....	....	....	1 .06	....	....	....	1 .01
III. ARACHNIDA	....	....	....	3 .05	....	....	....	....	....	....	1 .02	....	....	....	4 .01
Spiders	....	....	....	1 .05	....	....	....	....	....	....	....	....	....	....	1 .01
Mites	....	....	....	2 †	....	....	....	....	....	....	1 .02	....	....	....	3 †
IV. MYRIAPODA (Geophilus)	....	....	....	....	....	....	....	....	....	....	1 .01	....	....	....	1 †
V. VERMES (Lumbricus)	....	....	....	....	....	....	....	....	....	....	4 .25	....	....	....	4 .06
VEGETABLE FOOD	....	....	....	2 .06	1 .32	....	....	1 .20	1 1.00	....	5 .08	10 .91	1 .75	2 .65	23 .23
Seeds	....	....	....	....	....	....	....	....	....	....	....	3 .20	....	1 .32	5 .04
1. *Exogens*	....	....	....	2 .06	....	....	....	....	....	....	....	1 .10	....	1 .17	4 .03
2. *Endogens*	....	....	....	....	....	....	....	1 .20	....	....	1 .01	5 .50	....	1 †	10 .08
Gramineæ	....	....	....	....	....	....	....	....	....	....	....	4 .40	....	....	4 .06
Seeds	....	....	....	....	....	....	....	....	....	....	....	4 .30	....	....	4 .04
3. *Fungi*	....	....	....	....	....	....	....	....	1 †	....	2 .04	....	....	1 .16	4 .02
Peronospora	....	....	....	....	....	....	....	....	....	....	....	....	....	1 .16	1 .01
Ascomycetes	....	....	....	....	....	....	....	....	....	....	1 .02	....	....	....	1 †

CARABIDÆ, AND CABBAGE WORMS AND CHINCH-BUGS.

	Pterostichus.	Amara.	Chlænius.	Agonoderus.	Anisodactylus.	Harpalus.	Summary.	Agonoderus.
Number of Specimens Examined	3	1	1	1	2	4	12	10
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.							
ANIMAL FOOD	3 .67	1 .50	1 1.00	.....	1 .50	1 .10	7 .41	8 .51
I. INSECTA	2 .33	.....	1 1 00	.....	.....	1 .10	4 .20	3 .36
Larvæ	.....	.....	.....	.....	.....	.....	.....	1 .02
1. *Hymenoptera*	.....	.....	.....	.....	.....	.....	.....	1 .05
Lasius flavus	.....	.....	.....	.....	.....	.....	.....	1 .05
2. *Lepidoptera*	1 .33	.....	1 .60	.....	.....	.....	2 .13	.....
Caterpillars	.....	.....	1 .60	.....	.....	.....	1 .05	.....
Agrotis annexa	1 .33	.....	.....	.....	.....	.....	1 .08	.....
3. *Diptera*	.....	.....	.....	.....	.....	1 .10	1 .03	.....
4. *Coleoptera* (larvæ)	....	....	1 .30	.....	.....	.....	1 .03	.....
5. *Hemiptera*	....	.....	.....	.....	.....	.....	.....	5 .29
Aphides	.....	.....	.....	.....	.....	.....	.....	2 .08
Chinch-bugs	.....	.....	.....	.....	.....	.....	.....	4 .21
VEGETABLE FOOD	1 .33	1 .50	1 †	1 1.00	1 .50	4 .90	9 .59	7 .49
Seeds	.....	1 *	.....	.....	1 *	4 .90	6 .30	.....
1. *Exogens*	.....	.....	.....	.....	.....	.....	.....	2 .13
2. *Endogens*	1 .33	1 *	1 †	.....	.....	1 †	4 .08	2 .11
Grass	1 .33	1 *	.....	.....	.....	1 †	3 .08	.....
3. *Fungi*	.....	.....	.....	.....	.....	.....	.....	2 .02
Helminthosporium	.....	.....	.....	.....	.....	.....	.....	1 .01
Peronospora	.....	.....	.....	.....	.....	.....	.....	1 .01

CARABIDÆ. GENERAL TABLE.

	Calosoma.	Pasimachus.	Scarites.	Brachynus.	Galerita.	Loxopeza.	Calathus.	Platynus.	Evarthrus.	Pterostichus.	Amara.	Dicælus.	Chlænius.	Cratacanthus.	Agonoderus.	Anisodactylus.	Amphasia.	Bradycellus.	Harpalus.	Patrobus.	Summary.
No. of Specimens.....	11	2	6	1	17	3	6	3	7	13	6	3	23	1	15	31	5	1	19	2	175
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.																				
	11	2	6	1	17	2	5	2	7	12	2	3	22		9	5	2	1	7	1	117
ANIMAL FOOD.....	1.00	1.00	1.00	1.00	.93	.44	.67	.45	.93	.73	.23	1.00	.88	....	.34	.21	.07	1.00	.12	.33	.57
												1									1
I. MOLLUSCA (slugs).	....	....	....	....	....	....	....	....	....	....	....	.33	....	....	....	....	....	....	....	....	.01
	5		3		17	1	5	1	7	7			18		6	3	2	1	5	1	82
II. INSECTA.....	.45	....	.50	....	.86	.11	.67	.12	.93	.34	....	....	.67	....	.24	.05	.07	1.00	.09	.33	.36
					2		1		1				2		1						7
Larvæ.....	....	....	....	....	.09	....	.16	....	.07	....	....	....	.06	....	.02	....	....	....	....	....	.03
									1	1					1				1		4
1. *Hymenoptera*.....	....	....	....	....	....	....	....	....	.02	.07	....	....	....	....	.03	....	....	....	.01	....	.01
															1				1		3
Formicidæ.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.03	....	....	....	.01	....	†
															1						1
Lasius flavus.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.03	....	....	....	....	....	†
					11		2		3	2			10						2	1	31
2. *Lepidoptera*.....	....	....	....	....	.58	....	.33	....	.40	.10	....	....	.36	....	....	....	....	....	.06	.30	.15
					5		1		1	1			3						1	1	13
Larvæ.....	....	....	....	....	.18	....	.17	....	.14	.03	....	....	.05	....	....	....	....	....	.01	.30	.04
					7		1		2				4						1		16
Anisopteryx vernata.	....	....	....	....	.39	....	.16	....	.26	....	....	....	.18	....	....	....	....	....	.05	....	.08
					1								2								4
Noctuidæ (larvæ).....	....	....	....	....	.01	....	....	....	....	....	....	....	.09	....	....	....	....	....	....	....	.02
										1											1
Agrotis annexa...	....	....	....	....	....	....	....	....	....	.07	....	....	....	....	....	....	....	....	....	....	.01
					3		1		1				1			1			1		9
3. *Diptera*.....	....	....	....	....	.05	....	.01	....	.01	....	....	....	†	....	....	.03	....	....	.02	....	.01
									1												1
Culicidæ.....	....	....	....	....	....	....	....	....	.01	....	....	....	....	....	....	....	....	....	....	....	†
									2				2								4
4. *Coleoptera*.....	....	....	....	....	....	....	....	....	.28	....	....	....	.06	....	....	....	....	....	....	....	.02
									1				1								2
Larvæ.....	....	....	....	....	....	....	....	....	.14	....	....	....	.01	....	....	....	....	....	....	....	.01
									1												1
Scarabæidæ.....	....	....	....	....	....	....	....	....	.14	....	....	....	....	....	....	....	....	....	....	....	†
													1								1
Telephoridæ.....	....	....	....	....	....	....	....	....	....	....	....	....	.05	....	....	....	....	....	....	....	.01
								1							5					1	7
5. *Hemiptera*.....	....	....	....	....	....	....	....	.12	....	....	....	....	....	....	.19	....	....	....	....	.03	.02
								1							2					1	4
Aphides.....	....	....	....	....	....	....	....	.12	....	....	....	....	....	....	.05	....	....	....	....	.03	.01
															4						4
Chinch-bugs.....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.14	....	....	....	....	....	.01
					3					1	1		1		1				2		9
III. ARACHNIDA.....	....	....	....	....	.04	....	....	....	....	.01	.15	....	.01	....	†	....	....	....	.01	....	.01
					1																1
Spiders.....	....	....	....	....	.04	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	†
					2					1	1		1		1				2		8
Mites.....	....	....	....	....	†	....	....	....	....	.01	.15	....	.01	....	†	....	....	....	.01	....	.01
IV. MYRIAPODA (Geophilus)..	....	....	....	....	....	....	....	....	....	....	....	....	1 .01	....	....	....	....	....	....	....	1 †
V. VERMES (Lumbricus)..	....	....	....	....	....	....	....	....	....	....	....	....	5 .19	....	....	....	....	....	....	....	5 .02
					4	3	3	2	1	6	5		8	1	12	26	5		18	2	97
VEGETABLE FOOD	....	....	....	....	.07	.56	.33	.55	.07	.27	.77	....	.12	1.00	.56	.79	.93	....	.88	.67	.43
											2				2	7	1		6	1	19
Seeds.....	....	....	....	....	....	....	....	....	....	....	*	....	....	....	.13	.16	.18	....	.29	.50	.08
					2			1		2	1		1		2	1			4		14
1. *Exogens*.....	....	....	....	....	.04	....	....	.33	....	.08	.16	....	.02	....	.09	.03	....	....	.14	....	.05
										1											1
Seeds.....	....	....	....	....	....	....	....	....	....	*	....	....	....	....	....	....	....	....	....	....	*

CARABIDÆ. GENERAL TABLE—Concluded.

	Calosoma.	Pasimachus.	Scarites.	Brachynus.	Galerita.	Loxopeza.	Calathus.	Platynus.	Evarthrus.	Pterostichus.	Amara.	Dicælus.	Chlænius.	Cratacanthus.	Agonoderus.	Anisodactylus.	Amphasia.	Bradycellus.	Harpalus.	Patrobus.	Summary.
No. of Specimens	11	2	6	1	17	3	6	3	7	13	6	3	23	1	15	31	5	1	19	2	175
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.																				
Compositæ (pollen)																			3		3
																			11		.01
Ambrosia																			2		2
																			.11		.01
2. *Endogens*					1	1	2	1	1	2	1		4		3	12			6	1	36
					.02	.11	.17	.20	.07	.12	*		.01		.14	.37			.14	.10	.13
Gramineæ					1	1	2	1		1	1				2	36			5	1	25
					.02	.11	.17	.20		.08	*				.10	.34			.14	.10	.11
Seeds								1			1					5			1		8
								.20			*					.13			†		.03
Pollen						1	2														4
						.11	.17														.01
Phleum (seeds)															1	4					5
															.07	.13					.03
3. *Hepaticæ*																2					2
																†					†
4. *Algæ*									1				1								2
									†				†								†
Protococcus													1								1
													†								†
5. *Fungi*					1	3		1	1	3	1		3	1	4	3			6	1	29
					†	.45		.02	†	.04	.14		.06	1.00	.04	.03			.11	.07	.05
Coprinus													1								1
													.04								†
Phoma						2															1
						.45															.01
Coleosporium																1					1
																†					†
Dematiei													1								1
													†								†
Helminthosporium						2								1	1				2		6
						†								1.00	.01				†		.01
Cladosporium															1	1					2
															†	.01					†
Peronospora											1				1	1			2		5
											.12				†	†			.05		.01
Ascomycetes										1			1								2
										†			.01								†
Ramularia															1						1
															.03						†

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	12 .44	5 .64	....	17 .47	12 .25	...	2 .32	14 .25	24 .35	5 .53	2 .32	....	31 .37
I. INSECTA	11 .39	5 .64	....	16 .43	12 .25	....	2 .32	14 .25	23 .32	5 .53	2 .32	....	30 .35
1. *Lepidoptera*	1 †	....	....	1 †	1 .01	....	....	1 .01	2 .01	....	....	....	2 .01
Larvæ	....	....	....	....	1 .01	....	....	1 .01	1 .01	...	....	....	1 .01
2. *Hemiptera*	8 .29	5 .64	....	13 .36	7 .21	....	2 .32	9 .22	15 .25	5 .53	2 .32	....	22 .29
Aphides	8 .29	5 .64	....	13 .36	4 .11	....	2 .32	6 .14	12 .20	5 .53	2 .32	....	19 .26
Siphonophora granariæ	....	....	....	....	2 .05	....	1 .24	3 .08	2 .02	....	1 .24	....	3 .03
Chinch-bugs	....	....	....	....	4 .10	...	....	4 .08	4 .05	....	....	....	4 .03
3. *Neuroptera* (Podura)	1 .01	....	....	1 .01	....	....	....	....	1 †	....	....	....	1 †
II. ARACHNIDA (Mites)	4 .01	....	....	4 .01	2 †	....	....	2 †	6 .01	....	....	....	6 †
III. MYRIAPODA (Geophilus)	1 .04	....	....	1 .03	....	....	....	....	1 .02	....	....	....	1 .02
VEGETABLE FOOD	13 .56	2 .86	1 1.00	16 .53	14 .75	1 1.00	3 .68	18 .75	27 .65	3 .47	3 .68	1 1.00	34 .63
Pollen	1 .03	1 †	....	2 .02	....	....	....	....	1 .01	1 †	....	....	2 .01
1. *Exogens* (Pollen)	7 .13	....	....	7 .09	13 .07	....	3 .47	16 .13	20 .10	....	3 .47	....	23 .11
Compositæ	6 .13	....	....	6 .09	13 .07	....	3 .47	16 .13	19 .10	....	3 .47	....	22 .11
Taraxacum	1 .07	....	....	1 .05	....	....	....	....	1 .04	....	....	....	1 .03
Ambrosia	....	....	....	....	2 *	....	....	2 †	2 *	....	....	....	2 *
Polygonum	1 †	....	...	1 †	1 *	....	....	1 †	2 †	....	....	....	2 *
Coniferæ	1 †	....	....	1 †	...	....	....	....	1 †	....	....	....	1 †
2. *Endogens*	1 .05	....	....	1 .04	....	....	....	....	1 .03	....	....	....	1 .02
Gramineæ	1 .05	....	....	1 .04	....	....	....	....	1 .03	....	....	....	1 .02
Pollen	1 .05	....	....	1 .04	....	....	....	....	1 .03	....	....	....	1 .02
3. *Lichenes*	4 .02	1 .04	....	5 .02	11 .06	....	2 .03	13 .05	15 .04	1 .03	2 .03	....	18 .04
Physcia	1 .01	....	....	1 †	6 *	....	1 †	7 †	7 .01	....	1 †	....	8 .01
4. *Fungi*	11 .33	2 .32	1 1.00	14 .36	14 .61	1 1.00	2 .18	17 .56	25 .46	3 .44	2 .18	1 1.00	31 .45
Myxogastres	1 *	....	....	1 †	....	....	....	....	1 †	....	....	....	1 *
Sphæronemei	1 *	....	....	1 .01	....	..	...	....	1 *	....	....	....	1 *
Septoria	1 *	....	....	1 .01	7 *	....	1 *	8 *	8 *	....	1 *	....	9 *
Ustilago	1 *	2 .08	....	3 .02	2 *	....	....	2 *	3 *	2 .07	....	....	5 *
Uredo	....	....	....	....	1 *	....	....	1 *	1 †	....	....	....	1 *
Helminthosporium	6 *	1 .10	1 1.00	8 .17	11 *	....	1 *	12 *	17 *	1 .08	1 *	1 1.00	20 *
Macrosporium	3 *	....	....	3 .04	7 *	....	1 *	8 *	10 *	....	....	....	11 *
Cladosporium	3 *	....	....	3 .02	13 *	....	2 *	15 *	16 *	....	....	....	18 *
Peronospora	3 *	....	....	3 .01	7 *	....	....	7 *	10 *	....	....	....	10 *
Menispora	1 *	....	....	1 †	....	....	....	....	1 *	....	....	....	1 *

THE FOOD OF THE SMALLER FRESH-WATER FISHES.

By S. A. FORBES.

In a paper on the food of fishes, published in 1880,* I characterized the food of all the Illinois Acanthopteri, with the exception of the Aphredoderidæ; and in the present article, which is to be regarded as a continuation of that just mentioned, I propose to summarize my observations on all the smaller fishes occurring in the waters of the State, with the exception of the darters (Etheostomatinæ), which were treated in the preceding paper.

The purposes and methods of the investigation upon which the following discussion is based, are so similar to those already described, that they will not need any especial present explanation.

The data for it have been obtained by a minute and careful study of the contents of the alimentary canals of 319 specimens, belonging to twenty-five species, representing twenty-two genera and seven families, namely: Aphredoderidæ, Cottidæ, Gasterosteidæ, Atherinidæ, Cyprinodontidæ, Umbridæ, and Cyprinidæ.

An additional feature is the description of the structures subsidiary to alimentation, given, in this paper, for each genus, in order to furnish a basis for a more exact discussion of the relations of structure to food-habits than I attempted formerly. Under this head I have included the length and complication of the alimentary canal, the character of the pharyngeal structures, the number and development of the gill-rakers, and the presence of any peculiar prehensile apparatus about the mouth.

First giving for each species a brief account of its numbers and distribution throughout the State, I shall add for each genus a description of these alimentary structures, following this by a detailed statement of the observations made upon its food, and closing with a summary of such observations, and a discussion of the correlations of structure to food characters, given sometimes

*Bulletin No. 3, Ill. State Lab. Nat. Hist., pp. 18–65.

under the genus and sometimes under the special group to which the genus is assigned.

FAMILY APHREDODERIDÆ.

This family is represented by a single peculiar species (*Aphredoderus sayanus*), resembling the sun-fishes in most of its characters, but remarkably distinguished by the fact that the vent, although occupying the normal position in the young, opens in the adult far forward under the head, moving gradually to the front with increasing size. This fish is not over three inches in length. It occurs in rivers and smaller streams, as well as in lakes and ponds throughout the State. We have collected it from the Illinois River and various tributaries, as well as from the lakes connected with that stream, and from ponds and creeks throughout Southern Illinois. It has also been taken in the Calumet River near Chicago, and from lakes in that vicinity, but is not known to occur in Lake Michigan. It is said to be nocturnal in its habits, by Dr. C. C. Abbott, who kept specimens in an aquarium for some time.* The same author reports that in confinement it feeds voraciously upon small fishes, especially immature Cyprinidæ; and for this reason he bestowed upon it the name of *pirate perch*, by which it has become generally known among ichthyologists. The observations presently to be detailed will show, however, that his specimens were doubtless forced to feed so largely upon fishes for want of food more natural to them, since in their native haunts fishes make but a small percentage of their ordinary food.

The intestine of this species is short and simple, less than the length of the head and body without the tail, and distinguished only by the character previously mentioned. The gill apparatus is ineffective, the rakers being very short, thick, blunt, and few, and covered with short spinules. The pharyngeal jaws consist of small plates, covered with short, sharp spinulose teeth, similar to those of the sun-fishes. The mouth is large, but not remarkably protractile.

The specimens dissected number nineteen, representing seven different dates and localities, throughout Central and Southern Illinois. Some were taken from small temporary ponds left by

*Proc. Phil. Acad. Nat. Sci., 1861, p. 95.

the retreating overflow of streams, others from permanent lakes, and still others from creeks and rivers. The food from the different localities varies but little, on the whole, and it is scarcely worth while to discuss the separate collections. That of these nineteen specimens was almost purely animal, traces of a minute flowering plant (Wolffia), and small quantities of filamentous Algæ only being taken by two of the specimens. Fishes were eaten by but two, and were reckoned at two per cent. of the food of the whole. One of these found was recognizable as a Cyprinoid, but the other could not be determined. Insects amounted to more than ninety per cent., all of them aquatic, with the exception of a few gnats (Culicidæ) taken by eight of the fishes. Nearly half of the food consisted of larvæ of Chironomus and Corethra. Aquatic coleopterous larvæ were reckoned at eleven per cent., and specimens of Corixa, taken by three of the fishes, at two. A single fish had also eaten Galgulus. A fourth of the food consisted of neuropterous larvæ (Ephemeridæ and Libellulidæ). Crustaceans, though captured by more than half the fishes, made but four per cent. of the food. As far as recognized, this element consisted chiefly of the amphipod, *Allorchestes dentata*, and the common isopod, Asellus. A few specimens of Cypridida were noticed in two of the fishes, and Cyclops and other Copepoda were taken by five. One fish had eaten a Lumbriculus, a species closely allied to the common earthworm.

A careful comparison was made of the food of specimens of various ages — those, consequently, in which the situation of the vent was widely different — but no differences of food whatever were distinguishable. It is highly probable, consequently, that the explanation of this peculiar character must be sought elsewhere than in the food. With respect to the other relations of food to structure, we have at present only to note the coïncidence of fishes and aquatic insects as the principal elements of the food with the large mouth and inferior development of the gill and pharyngeal apparatus, and short and simple intestine.

FAMILY COTTIDÆ.

This curious family, chiefly marine, is represented in the State by several species from Lake Michigan, mostly from its deeper waters, and by a single one recently discovered in our streams.

POTAMOCOTTUS MERIDIONALIS, Gill. GOBLIN, BLOB.

Although this fish has not hitherto been recorded from the State, we have found it abundant in small streams in Southern Illinois, and a single specimen has been sent us from McHenry County, near our northern limits. The first of these situations is in a limestone region, where small caves are not infrequent; but the second is in an area deeply covered by drift, with rock nowhere exposed.

The general appearance of this fish is not unlike that of a catfish, the head being broad and flat, the mouth very large, and the skin smooth. The gill-rakers are few, short and thick, and of insignificant character; the pharyngeals are similar to those of Aphredoderus, but form thicker and larger plates; the intestine is short and simple, its entire length being less than that of the head and body.

Six specimens of this species, taken in Southern Illinois, had eaten only animal food, about one-fourth of which consisted of fishes, one of which was furnished with ctenoid scales. Undetermined aquatic larvæ (thirty-six per cent.) and other insects, were estimated at forty-four per cent. of the food. Crustacea, all belonging to the genus Asellus, eaten by two of the fishes, composed the remaining twenty-nine per cent. The general resemblance of the food of this species to that of Aphredoderus seemingly corresponds to the similar character of their alimentary structures.

FAMILY GASTEROSTEIDÆ.

Of the interesting little stickle-backs, two species were studied, only one of which is common in the State.

EUCALIA INCONSTANS, Kirt. BLACK STICKLEBACK.

This fish is abundant in streams and lakes in the northern part of Illinois, but has not been taken by us south of Rock River.

Its mouth is small; the gill-rakers are long and slender (about half as long as the corresponding filaments), but are not unusually numerous; the pharyngeal apparatus is insignificant or wanting; and the intestine is short and simple, not longer than the head and body together.

Four specimens from Rock River, and one from Cedar Lake, in Lake County, had divided their food about equally between plant and animal substances: the former, consisting wholly of filamentous Algæ, taken by four of the specimens in quantities to make it certain that they were ingested purposely. The animal food was about equally insects and crustaceans, the former nearly all aquatic larvæ of Diptera (Chironomus being the commonest form), and the latter chiefly Entomostraca, of which Cladocera were the most abundant. One of the specimens had eaten Cypris — some of them *Cypris vidua*. Cyclops was also noticed in three of the fishes, and amounted to three per cent. of the food.

The herbivorous character of this fish seems not to be related to any structural facts; but the occurrence of the large ratio of Entomostraca is at once accounted for by the well-developed gill-rakers, these serving as a straining apparatus by means of which the fishes possessed of it are able to appropriate minuter organisms than would otherwise be available for their food.

PYGOSTEUS PUNGITIUS, Lac. MANY-SPINED STICKLEBACK.

This species has hitherto been found by us only in Lake Michigan, and in Calumet River near its mouth.

But two specimens were dissected; and these had fed wholly on larvæ of Chironomus and Simulium (sixty per cent.), and on Chydorus and other Cladocera (forty per cent.).

With so small an amount of material to illustrate the food of the family, we can only say that it evidently consists chiefly of aquatic larvæ and Entomostraca, together with a considerable percentage of vegetable substances. In the absence of any apparatus for mastication, the latter will doubtless be found to consist of Algæ, as in the cases examined.

FAMILY ATHERINIDÆ.

LABIDESTHES SICCULUS, Cope. SILVERSIDES.

This elegant little fish, the only fresh-water representative of its family, is generally abundant throughout the State, and has been collected by us in a great variety of situations, from the northern lakes to the Wabash River.

It is long and slender, the mouth small and well furnished with

teeth, while the throat is destitute of special pharyngeal apparatus. The gill-rakers are unusually well developed, being numerous, slender, finely toothed, and longer than the corresponding filaments of the gills. Taking into account the small size of the fish, and the consequently small diameter of the apertures of the mouth and gills, it will be seen that it is provided with an especially effective straining apparatus. The intestine is unusually short, the entire alimentary canal measuring considerably less than the length of the body without the head.

The following account of its food is derived from the dissection of twenty-five specimens, obtained from Crystal Lake, Fox River, and Calumet River in Northern Illinois, from Peoria and Mackinaw Creek in the central part of the State, and from Little Fox River in the Wabash Valley. The food of these specimens was purely animal, a little over half consisting of insects, and a little less than half of crustaceans. The larvæ of Chironomus were among the most important elements of the food, standing at thirty per cent. of the whole. The crustaceans were all Entomostraca, and represented a great variety of both Copepoda and Cladocera, although none of the specimens examined happened to have eaten Ostracoda. Among the Cladocera recognized were *Daphnia pulex*, *retrocurva* and *hyalina*, *Simocephalus americanus*, Bosmina, Chydorus, Pleuroxus, Alona, and Eurycercus; and among the Copepoda were *Cyclops thomasi*, Canthocamptus, Diaptomus, Limnocalanus, and *Epischura lacustris*. Spiders and terrestrial insects, accidentally washed or fallen into the water (the latter including Chalcididæ, various Diptera, plant-lice, Tettigonidæ, Thrips, and Podura), amounted to twelve per cent. of the food. The only peculiarities of food corresponding to differences of locality were found among the group from the northern lakes, in which the Chironomus larvæ were present in diminished ratios, while the Cladocera were more abundant.

FAMILY CYPRINODONTIDÆ.

This family consists, in Illinois, of four species, one of Fundulus and three of Zygonectes.* The family is divided into two sections, *carnivorous* and *herbivorous*, by Dr. Günther in his "In-

*I do not consider *Fundulus menona*, Jor. and Cope., as distinct.

troduction to the Study of Fishes." Although our genera both belong to the carnivorous section, it will be seen that they are not by any means strictly confined to animal food, vegetation making about one-fifth of their usual nutriment.

FUNDULUS DIAPHANUS, LeS. BARRED KILLIFISH.

This species is very abundant in the northern part of the State, especially in lakes or in clear and sandy streams, but we have not taken it anywhere in Central or Southern Illinois. Most of our collections were made in the lakes of Lake and McHenry Counties.

The intestine is shorter than the body, the gill-rakers are short, obtuse, and few in number, the pharyngeal jaws are of the pavement type, set with fine, sharp teeth, and the mouth is small, but extraordinarily protractile.

Eight specimens were studied, from Crystal and Cedar Lakes. About four-fifths of the food consisted of animal substances, the remaining fifth of vegetation. Except a few filamentous Algæ taken by one of the specimens, the latter consisted wholly of seeds of various plants fallen into the water. Eighty per cent. of the food of two of the specimens, and twenty per cent. of that of a third consisted of such seeds; ratios evidently too large to have been taken accidentally. Two of the specimens had eaten Planorbis, and all had eaten insects, which made about forty per cent. of the food; terrestrial species, including spiders, making twelve per cent. Among the aquatic forms were Chironomus larvæ, Hydrophilidæ, and larvæ of Ephemeridæ, the latter eleven per cent. Crustacea were a fifth of the food, chiefly the abundant amphipod, *Allorchestes dentata*. Cypris and Candona were likewise noticed in considerable quantity (seven per cent.), and a few specimens of various Cladocera occurred.

ZYGONECTES NOTATUS, Raf. TOP MINNOW.

This species ranges in ponds and sluggish streams throughout the State, but is most abundant southwards. Here it may commonly be seen swimming slowly about in stagnant pools, with the head at the surface of the water, as if interested in the phenomena of the weather, or possibly watching for the appearance of terrestrial insects. The alimentary structures are in all respects similar

to those of Fundulus, except that the intestine is possibly a little longer, being about equal to the head and body. The only striking peculiarity is the depressed head, with the mouth placed at the upper angle and opening obliquely upward. This, with the surface-swimming habit of the fish, has given rise to the supposition that it feeds largely upon surface insects; but I did not find this to be the case, as the seventeen specimens studied contain no example of an insect of this character.

These specimens were taken from a considerable variety of situations throughout Central and Southern Illinois, and at various times of the year. The animal food amounted to about ninety per cent. of the whole. Vegetation, almost wholly filamentous Algæ, was taken by ten of the specimens, but in such quantities by various individuals as to make it certain that its presence was not accidental. In one, for example, the intestine was packed with these Algæ to the exclusion of all other food, and in three others this made more than half the whole. One specimen had also eaten Wolffia. Mollusks (Physa) had been eaten by three, and insects amounted to seventy-three per cent. Spiders and various terrestrial insects made fully a fourth of the food. Philhydrus, taken by three of the specimens, was reckoned at eight per cent. Corixa and other aquatic Hemiptera amounted to eleven per cent., and larvæ of Agrion to three. Crustacea were estimated at only six per cent. They included *Crangonyx gracilis*, and various Cladocera, Ostracoda and Copepoda. Among the Entomostraca recognized were Daphnia, Chydorus, Pleuroxus, Acroperus, Cypris, and Cyclops. Chironomus larvæ were about one per cent., taken by only two of the specimens.

ZYGONECTES INURUS, Jor. and Gilb. BLACK-EYED TOP MINNOW.

ZYGONECTES DISPAR, Ag. STRIPED TOP MINNOW.

The first of these species is peculiar in this State, as far as known, to Southern Illinois, not having been taken by us north of White County. The second ranges throughout.

Six specimens of the first and two of the second were studied. The food characters presented do not differ sufficiently from those of *Zygonectes notatus* to make it worth while to treat them separately, and a summary for the genus will be given instead.

Four-fifths of the food of the genus consisted of animal matter, nearly one-quarter being Mollusca, including Physa, Planorbis, and *Valvata sincera*. Insects make less than half, and nearly half of these were of terrestrial origin. Chironomus larvæ, usually so abundant in the food of insectivorous minnows, occurred here in only trivial quantity. Specimens of Philhydrus were eaten by three of the fishes. *Corixa alternata* amounted to five per cent. of their food, Agrion larvæ and case worms (Leptoceridæ) to two per cent. Crustaceans were only four per cent. of the whole, partly Amphipoda, but chiefly Entomostraca. The vegetable food (sixteen per cent.) was chiefly Wolffia, taken by five of the specimens from southern lakes. Ten individuals had, however, eaten filamentous Algæ.

Summary.

The only essential difference between these two genera exhibited by the specimens studied, is the much larger ratios of terrestrial insects captured by Zygonectes, this genus eating nearly twice as many as the other. This fact is possibly related to the surface-swimming habit already mentioned, but is more likely due to the smaller bodies of water in which the top minnows occur. Concerning the food of the family as a whole, the salient characters are the presence of a considerable quantity of vegetable food, (about twenty per cent.) the occurrence of fifteen per cent. of Mollusca, the insignificant quantity of Crustacea eaten (four per cent.), and the importance of terrestrial insects as a source of support.

FAMILY UMBRIDÆ.

UMBRA LIMI, Kirt. MUD MINNOW.

This species, the only one of its family in Illinois, is very abundant in muddy ponds and ditches, and has been collected by us from Lake to Union Counties.

The intestine is short, less than the body in length; the gill-rakers are thick and rather long, about one-half the length of the filaments, and the pharyngeal apparatus is wholly insignificant.

Ten specimens were studied, from six localities, all from Southern Illinois but one, which was taken in Calumet River. Vegetable food amounted to forty per cent., chiefly Wolffia, eaten by

seven of the specimens from Southern Illinois lakes. A considerable quantity of unicellular Algæ was also taken by one. Mollusks, eaten by two, were reckoned at five per cent., all Physa. Insects drop to fourteen per cent., chiefly undetermined larvæ. No terrestrial forms were recognized. Corresponding to the greater development of the gill-rakers, we find the Entomostraca assuming greater importance in the food. These were reckoned at ten per cent.; three per cent. additional consisting of *Crangonyx gracilis*.

FAMILY CYPRINIDÆ.

This family includes all the fishes properly known as "minnows," embracing, in fact, by far the larger part of the smaller fishes of the State. Both in number and in variety of species it is much the most important family of fresh-water fishes. It includes, in Illinois, about forty species, nearly or quite one-fourth of the whole number known to occur in our territory. They occur in all waters from the Mississippi River and Lake Michigan to the smallest streams and ponds; but are much the most abundant in creeks and rivulets. The species differ greatly with respect to their favorite haunts, some affecting the principal lakes and larger rivers, others occurring most commonly in clear and rapid brooks, while still others are most frequent in the sluggish and muddy streams of prairie regions. The principal economic interest of the fishes of this family is due to the well-known fact that they furnish an important part of the food supply of larger species.

But little has hitherto been done upon their food in the United States. In fact, I have seen nothing more accurate or comprehensive than the following general statement made by Prof. Cope, in his paper on the Cyprinidæ of Pennsylvania:*

"These differences of habit are associated with peculiarities of food and of the structure of the digestive system. Few families of vertebrates embrace as great a variety in these respects as the present one. There are carnivorous, insectivorous, and graminivorous genera, which are distinguished as among mammalia, the former by the abbreviation, the last by the elongation of the ali-

*Trans. Amer. Philosophical Society, Vol. 13, New Series, page 353.

mentary canal, in the former the teeth are usually sharp-edged or hooked, in the latter truncate, hammer, or spoon-shaped."

"In the American genera, as far as included in the scope of this essay, the peculiarities of the intestines correspond with the food. In the *Alburnellus rubrifrons*,[1] they are but four-fifths the length of head and body (excluding caudal fin). In *Hypsilepis kentukiensis*,[2] *Photogenis leucops*, *Argyreus atronasus*[3] and *nasutus*,[3] *Ericymba buccata*, and *Exoglossum maxillingua*, about seven-ninths; the food of the last five species is insects and crustaceans, the last depending largely on mollusca. In the species of Ceratichthys, Semotilus, and Hybopsis, with *Hypsilepis cornutus*,[4] fifteen-sixteenths to equal the length; the habits insectivorous. The genera with longer intestines are, first, Stilbe[5] one and two-fifths to one and three-fourths the length; Chrosomus, Hyborhynchus, and Pimephales two and two-fifths to two and two-thirds, and Hybognathus four times. The intestines in these are generally filled with a soft, dark-colored slime, without remains of insects, but of vegetable origin. In the remarkable genus Campostoma the canal extends to between eight and nine times the length, and, like that of other vegetable feeders, is usually found occupied by the ingesta for a considerable part of its length."

This statement is in the main correct as far as it goes, but it will be seen from the following data, and from the discussion of the food of the family, that it is far from the truth with respect to the genus Campostoma and its allies.

If we examine the alimentary structures of the Cyprinidæ, to which reference has been made in describing the food of the preceding families, we shall find these fishes easily divided into at least four tolerably distinct groups, defined by characters drawn from the gill-rakers, the pharyngeal teeth and the intestines. In all but two of the genera of this paper* the gill-rakers are short and insignificant. The pharyngeal teeth may be either hooked or plain, and with or without grinding surface, while the intestine varies in length from less than that of the body without the head

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[1]Minnilus or Notropis. [2]Photogenis analostanus. [3]Rhinichthys. [4]Luxilus cornutus. [5]Notemigonus.

*I have used here, for convenience' sake, the nomenclature of the Catalogue of the Fishes of Illinois, published in our third bulletin.

to seven or eight times the length of the head and body together. For convenience' sake I have grouped the genera as follows:

Group I.—Intestine long. Pharyngeal teeth not or slightly hooked, with grinding surface.

Campostoma, *Pimephales*, *Hyborhynchus*, *Hybognathus*.

Group II.—Intestine rather long. Teeth hooked, with grinding surface.

Notemigonus, *Chrosomus*.

Group III.—Intestine short. Teeth hooked, with grinding surface.

Hybopsis, *Luxilus*, *Lythrurus*, *Hemitremia*, *Platygobio*.

Group IV.—Intestine short. Teeth hooked, without grinding surface.

Minnilus, *Photogenis*, *Ericymba*, *Phenacobius*, *Semotilus*, *Ceratichthys*, *Rhinichthys*.

The second group, consisting of Notemigonus and Chrosomus, may be again divided according to the development of the gill-rakers, which are numerous, long, and slender in Notemigonus; few, short, and insignificant in Chrosomus.

Food of the Young.

The genera and species of Cyprinidæ are not easily recognized, even in the adult, the characters upon which they are based being often either trivial or extremely variable; and when one has to do with individuals small enough to show the earliest food of the family, it is commonly quite impossible to identify even the genus. In the few specimens which I have studied, I have not attempted such determination, although I have reason to believe that most of those examined belong to some species of Minnilus.

Their food was so far peculiar, as compared with the young of other families, that I will describe in detail that found by dissecting six specimens under an inch in length. The first of these, three-eighths of an inch long, taken in Fox River on the 8th of July, had eaten only a small Chironomus larva, and a single example of Bosmina. Two specimens, six-tenths of an inch long, captured in August in a creek in Central Illinois, had derived their food from quite different sources. Filaments of Spirogyra and other filamentous Algæ, cells of Cosmarium and Closterium,

and Cymatopleura and other diatoms, and spores of Ustilago, were the vegetable elements, while the head of a Chironomus larva and great numbers of the ciliate infusorian *Euglena viridis*, and a few specimens of *Euglena acus*, represented the animal kingdom. Full half the contents of these intestines consisted of the Protozoa mentioned. A third specimen of the same length, taken from the Illinois River in June, had derived about eight-tenths of its food from Bosmina, the remainder consisting of a small Chironomus larva and a minute larval hydrachnid. In a specimen seven-tenths of an inch long, taken in Mackinaw Creek in August, *Euglena viridis* was the most abundant object, making about six-tenths of the food; and *Euglena acus* and a species of Phacus also occurred. Various filamentous Algæ, specimens of Closterium and Cosmarium, and numbers of diatoms were the remaining elements. In another specimen, taken at the same time and place, about three-fourths of an inch in length, fungi and fungus spores amounted to more than half the food, although the same forms of Algæ occurred as before, together with a few examples of *Euglena viridis* and Difflugia. A Chironomus larva, a plant-louse, and some other insect not determined, had also been eaten.

From the above we may conclude that the young Cyprinidæ draw almost indiscriminately, for their food supply, upon Protozoa, Algæ, and Entomostraca, differing in this respect from the young of all the other families which I have studied, with the exception of the Catostomidæ. It is worthy of note, as a suggestive coïncidence at least, that the other families just mentioned which were found to take Entomostraca and Chironomus larvæ as their earliest food, were all possessed of raptatorial teeth on the jaws when very young; whereas in young suckers and Cyprinidæ, the mouth is unarmed at all ages.

Group I.

Intestine long. Pharyngeal teeth not hooked, with grinding surface.

Campostoma anomalum, Raf. Stone Lugger.

This very peculiar fish is exceedingly abundant everywhere except in the great lakes. I have taken it in streams of all magnitudes, from the Illinois River to the smallest creeks, but have not yet encountered it in Lake Michigan or in stagnant pools. It is commonest, however, in swift creeks of medium size.

It is distinguished from all other species by the great length of the intestine, which is from six to nine times the length of the body, and is spirally coiled about the air bladder. The gill-rakers are numerous, about twenty in number to each gill, but are very short, scarcely projecting beyond the anterior margin of the arch. They are evidently almost totally inefficient as a straining apparatus.

Of the great number of specimens available for dissection, only nine were studied, since the contents of the intestines were found so uniform in character that it was not deemed worth while to multiply instances. These were from both extremes and also from the center of the State, but were all taken in July, August and September. The intestine was invariably filled from end to end with a black and slimy matter, which, when examined under the microscope, was found to consist almost wholly of fine mud. When the intestine was emptied and the contents stirred up in alcohol and repeatedly decanted so as to separate the coarser fragments, the organic matter was easily distinguished. It made on an average, only about one-fourth of the contents of the intestine, the remainder consisting of the finest particles of sand and clay. Not far from one-fifth of the whole amount was of vegetable origin, consisting chiefly of filamentous Algæ, mingled with a few diatoms, but comprising occasionally minute fragments of other kinds of vegetation also. The only animal objects noted were occasional Chironomus larvæ and Difflugia. Sometimes the intestine was wholly filled with almost pure mud, in which no organic structures whatever could be detected. Date and locality seemed to make no material difference in the food of this fish, which should evidently be classed as limophagous. The ratios of animal to vegetable food were scarcely different from what one would expect to find in the intestine of a fish which had the habit of swallowing mud rich in organic matter, the greater ratios of vegetation being apparently due to the fact that plants are more abundant in the water than animals.

PIMEPHALES PROMELAS, Raf. BLACK HEAD.

This species is generally distributed throughout Central and Northern Illinois, but is not very abundant. We have taken it only in rivers and larger creeks, but have not found it south of Jersey County.

The alimentary canal is two or three times the length of the body, and the gill-rakers are fifteen in number and somewhat more prominent than usual, those on the posterior part of the first arch being about one-third the length of the corresponding filaments.

Only four specimens were studied, one from the Pecatonica River at Freeport, and three from Otter Creek in Jersey County. With this fish as with the preceding, about three-fourths of the contents of the intestine consisted of mud, the remainder being almost wholly insects. These were partly terrestrial species, occurring accidentally in the water, and partly aquatic larvæ of Diptera. The vegetable food of these specimens amounted only to about one per cent., chiefly various unicellular Algæ.

HYBORHYNCHUS NOTATUS, Raf. BLUNT-NOSED MINNOW.

This extremely abundant minnow occurs in streams and rivers throughout the State, but has not been found by us in ponds. Specimens were taken, however, in the small lakes of Northern Illinois.

The intestine is about two and one-half times the length of the head and body. The gill-rakers are few, short and thick, being about one-fifth of the length of the corresponding filaments.

Nine specimens were studied from all parts of the State, when their food proved to be so uniform in character that further observations were deemed unnecessary. Mud made about eighty per cent. of the contents of the alimentary canal, the remainder consisting of unrecognizable vegetable debris, with a few filaments of Algæ. Undeterminable insects occurred in one, and a single specimen of Cypris in another.

HYBOGNATHUS NUCHALIS, Ag. BLUNT-JAWED MINNOW.

This species is likewise generally distributed in rivers, creeks and ponds, occurring in our collections from Galena to Cairo, and at a great number of points intermediate.

The alimentary canal in this genus is elongate, being about four times the length of the body. The gill-rakers are few and rather short, triangular in form, and about one-fourth to one-fifth the length of their corresponding filaments.

Eight specimens of this species were dissected, with results in

all respects similar to those given for the other members of this group. Filamentous Algæ, diatoms, and a few accidental fungus spores, were the only objects found imbedded in the quantities of mud which filled each intestine.

Summary of the Group.

If we average the results of the four species studied, belonging to this first group, we shall find that about three-fourths of the contents of the stomach and intestine consist of soft, black mud, the remaining fourth being derived from both animal and vegetable substances, about three times as much from the latter as from the former. The animal food is chiefly insects, both terrestrial and aquatic, and the vegetation is divided about equally between Algæ and miscellaneous fragments of higher plants. This group, with long intestine and grinding pharyngeals, is consequently to be considered as essentially limophagous. We find this peculiar form of pharyngeal teeth associated only with intestines of this type.

Group II.

Intestines moderately long; pharyngeal teeth hooked, with grinding surface.

Chrosomus erythrogaster, Raf. Red-bellied Dace.

This species is locally abundant, although not generally common. It occurs in clear streams in the northern part of the State, but has not been taken by us in Central or Southern Illinois.

The length of the fish is contained one and two-thirds times in the length of the intestine; the gill-rakers are few and rather short, triangular, acute, and about one-fifth the length of the corresponding filaments.

I examined carefully but three specimens of this species, derived from two localities. These were alike in the presence of great quantities of mud, which amounted to about eighty-seven per cent. of the contents of the intestine. The animal food was confined to a trace of Cladocera. The vegetation amounted to thirteen per cent., partly tissues of aquatic plants, with traces of fungi, but chiefly Algæ of various forms, including a little Oscillatoria.

NOTEMIGONUS CHRYSOLEUCUS, Mitch. SHINER.

This extremely abundant minnow, commonly called the shiner, occurs in all waters throughout the State, from the largest rivers to the smallest creeks, and from Lake Michigan to small stagnant ponds.

The intestine is shorter than in any of the preceding species, although still rather long, the head and body being contained one and one-third times in its length. The gill-rakers are long, fine, and numerous, about twenty in number on the anterior arch, and fully one-third the length of the corresponding filaments, making, therefore, an effective apparatus for the separation of the Entomostraca from the water. As this fish presents a peculiar combination of alimentary structures, and as its food was found unusually various, a larger number of specimens were studied than of any of the species already discussed.

Twenty-five fishes were dissected, from a great variety of situations in all parts of the State, and representing various dates from May to September inclusive. As the food differed widely according to situation, that of specimens from certain localities being more widely different than the food of different species has usually been found, it will be best to mention the most conspicuous differences depending upon situation.

Specimens taken from the Pecatonica River at Freeport, an extraordinarily muddy stream, noted for the abundance of its mollusks, had eaten no other food than univalve Mollusca, chiefly *Valvata tricarinata* and *Planorbis deflectus*. Another, from the Illinois River at Pekin, had also eaten largely of mollusks, while three taken in Otter Creek in Jersey County, in almost stagnant reaches of the stream, extremely muddy, and green with Algæ, had filled their intestines with mud, like Campostoma; and still others from ponds near Normal had eaten only Entomostraca, about equally Cladocera and Copepoda. Another specimen from the Illinois River had taken similar food, all Daphnias. One specimen from Nippersink Lake, in the northern part of the State, was full of wild rice (Zizania). Taking all these groups together, and considering the species as a whole, besides the mud already mentioned, about fourteen per cent. of the food consisted of mollusks, and only six per cent. of insects, nearly all of which were of

terrestrial species. Crustaceans amounted to fifteen per cent., all Entomostraca. Vegetation stands at fifty per cent., more than half of it accidental vegetable debris, partly from aquatic and partly from terrestrial plants. About one-fifth of the food consisted of Algæ, half of which was filamentous in character, and the remainder desmids, including Closterium, and various diatoms.

The peculiar character of the alimentary structures of this species are very clearly reflected in this summary of its food, the elongate intestine corresponding to the presence of mud, and the well developed gill-rakers to the occurrence of Entomostraca. I have not yet noticed any structural peculiarity of the Cyprinidæ related to the habit of feeding upon mollusks.

Summary for the Group.

The two species foregoing agree only in their mud-eating propensity, — probably habitual in one and occasional in the other,— the first having the longer intestine, and the second the longer gill-rakers. To this last difference we doubtless must trace the different relations of these fishes to Entomostraca.

I find nothing whatever, by comparison of the food of these specimens with those of the preceding group, to show the meaning of the hooked form of the pharyngeal teeth.

Group III.

Intestine short, teeth hooked, with grinding surface.

This group includes Hybopsis, Luxilus, Lythrurus, Hemitremia, and Platygobio. My studies were limited to three genera: Hybopsis, Luxilus and Hemitremia.

Hybopsis hudsonius. Clint. Spawn-eater.

This fine minnow is common everywhere to the northward, especially in Lake Michigan and the other lakes of Northern Illinois, but not abundant south of the central part of the State, although it has been taken to its extreme southern limit. It has never occurred in our collections in the smaller streams, but is confined to the lakes, rivers, and creeks of some magnitude.

The gill-rakers of this minnow are short and few.

Seventeen specimens were studied, from Lake Michigan,

Nippersink Lake and the Illinois River. Mud was found in noticeable quantities only in a single specimen, and there in small amount. About seventy per cent. of the food consisted of animal substances, three per cent. being fishes, taken by two of the minnows. One had also eaten a small bivalve mollusk. Insects made half the food, about one-third of them of terrestrial species (Rhynchophora), the remainder being chiefly larvæ of ephemerids. A few Chironomus larvæ and an aquatic hemipter, were the only other kinds determined. Crustacea amounted to thirteen per cent., nearly all Ostracoda (*Cypris vidua*) taken by two of the specimens from Chicago. Vegetable food stands at thirty-one per cent., eaten by ten of the specimens. One-third of this consisted of Algæ, chiefly of the filamentous forms, the remainder being miscellaneous fragments of exogenous plants, chiefly evidently aquatic.

Local and individual peculiarities.—The general summaries of the food of so many individuals from so great a variety of situations often disguise interesting and important facts relating to the food resources of the species, since an element taken in large quantity by one or two specimens may figure in the general average in such an insignificant ratio as to lead to the inference that its occurrence is merely accidental. In other words, general averages for a variety of situations will not necessarily indicate all the food resources open to the species. These can only be demonstrated by exhibiting the *peculiarities* of the record as well as its general average characters. For example, the fact that only eleven per cent. of the food of this species consisted of Algæ has a somewhat different aspect when we learn that one of the specimens had eaten nothing else, and that they made three-fourths of the food of another. Three specimens had eaten only insects, and these made ninety per cent. or more of the food of three others. Two had eaten nothing but Entomostraca, all the *Cypris vidua* previously mentioned. Vegetable structures made the entire food of four, and ninety per cent. or more of the food of three other specimens. Three out of four individuals taken at Nippersink Lake in May, had derived from ninety to one hundred per cent. of their food from terrestrial beetles of a single family (Rhynchophora), while ephemerid larvæ occurred in the food of three others in ratios exceeding seventy-five per cent.

HYBOPSIS STRAMINEUS, Cope. STRAW-COLORED MINNOW.

This insignificant species has been found by us in rivers and small streams throughout the State.

The gill-rakers were few and short.

Only five specimens were studied, all from rivers in Central Illinois. About three-fourths of their food consisted of animal matter, nearly all neuropterous larvæ (fifty-eight per cent.), Ephemeridæ standing at forty-eight per cent., and case-worms at ten. Crustacea were ten per cent., all Cyclops except a trace of Canthocamptus. About one-fourth of the food was vegetation, chiefly seeds of grasses, occurring, of course, only accidentally in the water. Two had derived from ninety to one hundred per cent. of their food from ephemerid larvæ, and four of the five had eaten vegetation amounting to as much as eighty per cent.

LUXILUS CORNUTUS, Raf. SHINER.

This large and fine minnow is probably the commonest fish in Illinois, occurring in lakes and streams of all sizes everywhere throughout our limits.

The gill-rakers are short and few, and of insignificant development, and the intestine is shorter than the head and body.

Twenty-one specimens were studied, from all parts of the State and at various seasons of the year. Animal food amounted to two-thirds of the whole, fourteen per cent. being fishes, eaten, however, by only one of the specimens. Insects, eaten by nineteen, were reckoned at forty-five per cent., only one-fourth of them terrestrial. Gyrinid larvæ, Corixa, and larvæ of *Palingenia bilineata* were among the forms recognized. The crustacean ratio was insignificant, standing at only three per cent., all the abundant amphipod, *Allorchestes dentata*, with the exception of traces of a considerable variety of Entomostraca, including Chydorus, *Acroperus leucocephalus*, and Cypris. One of the water-worms (Lumbriculus) was noticed in a single specimen. Vegetable food was reckoned at thirty-eight per cent., only about one-third of it consisting of Algæ, and the rest of accidental fragments, including the seeds, anthers, and pollen of plants, with a little Potamogeton and various forms of fungus spores. One of the commonest of the Algæ was *Cladophora glomerata*,* taken

*Kindly determined for me by Rev. Francis Wolle, Bethlehem, Pa.

by those from Effingham. The fact has already been noted that one of the specimens had eaten only fishes. Five had confined themselves to an insect diet, while twelve had derived more than half their food from the vegetable kingdom, one of them eating ninety-five per cent. and another one hundred.

HEMITREMIA HETERODON, Cope. NORTHERN HEMITREMIA.

This species, extremely abundant in Northern Illinois, has not been taken by us south of the central part of the State. North of Rock River it has been generally found in streams and lakes of all descriptions, from Lake Michigan down.

The gill-rakers are few in number, but thick, triangular, and rather long, those on the posterior part of the arch being from a fourth to a third the length of the filaments. The intestine is contained one and one-fourth times in the length of the head and body.

Eighteen specimens were studied, suitably distributed as to time and place. A little mud was found in the stomach of one. Only about one-tenth of the food consisted of vegetation, chiefly flowers and seeds. Traces of filamentous Algæ occurred in two of the specimens. Univalve Mollusca were noticed in one, and insects in twelve, amounting to more than a fourth of the entire food. These were chiefly larvæ of Chironomus (twenty per cent.), ephemerid larvæ occurring in but one. Crustacea were reckoned at fifty-eight per cent., all Entomostraca, with the exception of a single *Allorchestes dentata*. About two-thirds of these were Cladocera, the remainder being Ostracoda and Copepoda. Rotifers and Protozoa also rarely occurred, the latter including Centropyxis and Difflugia. Five of the specimens had eaten Entomostraca only, and two others ninety per cent. or more. Only two had derived more than half their food from vegetable sources.

It will be seen that the peculiar fact with respect to this species was the large per cent. of Entomostraca appropriated. I find nothing in the structure of the fish to explain this circumstance, other than the somewhat unusual development of the gill-rakers and the small size of the species. The latter probably had more to do with it than anything else. It should be noted, however, that nearly half the specimens were derived from places where Entomostraca were excessively abundant at the time of their capture.

Summary of the Group.

Taking now this group as a whole, we remark, first, the absence of mud mingled with their food, as related to the greatly diminished length of the alimentary canal. We have now also a decided predominance of animal food, which is about three-fourths of the entire amount, and note likewise the first occurrence of fishes. Although Mollusca occur in this group, it is in quantity too small to appear in the ratios. Insects make about half the food of all, nine per cent. being terrestrial forms. The larvæ of Neuroptera are by far the most important insect species, and stand at twenty-five per cent. Entomostraca make a fifth of the whole food, distributed among all the orders. The vegetation eaten was largely of a purely miscellaneous and incidental character, only about a third of it being derived from aquatic plants.

Group IV.

Intestine short; teeth hooked, without grinding surface.

This group, organized more strictly for predatory purposes than any of the preceding, contains also the largest number of genera, embracing nine of those occurring in Illinois. It was not thought necessary to study all of these, and my dissections were confined to five of them, namely: to Minnilus, Photogenis, Phenacobius, Semotilus and Ceratichthys.

Minnilus atherinoides, Raf. Emerald Minnow.

This species is everywhere abundant in streams and lakes, but does not occur in ponds. It is most common northward, swarming in summer along the shores of Lake Michigan.

The gill-rakers are short, triangular, and about one-fourth the length of the filaments; and the intestine is less than the length of the head and body.

Eighteen specimens were studied, all from the northern half of the State. The food was almost strictly animal, but five per cent. consisting of vegetation, and this chiefly of accidental character, occurring in trivial ratios. Only a single specimen had taken about forty per cent. of its food from filamentous Algæ. A minute fish had been eaten by one of these minnows. Insects

made two-thirds of the food, nearly two-thirds of them being terrestrial. Neuropterous larvæ were the principal aquatic forms, chiefly case-worms and larvæ of ephemerids. The Crustacea (twenty-two per cent.) were all Entomostraca, about two-thirds of them Cladocera, the remainder Copepoda. Among the former Bosmina and Chydorus were recognized, and Diaptomus among the latter.

Six of this species had eaten only insects, and these made ninety per cent. of the food of two others. One had filled itself with the larvæ of *Bibio albipennis*, a terrestrial grub abundant in early spring. Three from Peoria Lake, captured in October, had eaten Cladocera only, nearly all a single species, *Bosmina longirostris*.

PHOTOGENIS ANALOSTANUS, Grd. SILVER FIN.

Excessively abundant in streams of all sizes.

The gill-rakers are short, triangular, about one-fourth of the length of the filaments. The intestine is shorter than the head and body.

Thirty-three specimens of this species were examined. Two-thirds of the food was insects, seven per cent. fishes, taken by three individuals, and one per cent. spiders, bringing the ratio of animal food up to seventy-one per cent. Besides these, a Limnæa was eaten by one, and traces of Cladocera and Copepoda occur in three. Nearly half the insects were terrestrial, Corixa and neuropterous larvæ being the most important aquatic forms. The vegetable food (twenty-nine per cent.) was nearly all of terrestrial origin, about one-third consisting of Algæ, both filamentous and unicellular, including Spirogyra and Gloeocystis. Seeds, anthers and pollen of plants, and fragments of grass-like vegetation were noticed.

Eight of the specimens had taken only insects, and in two others these amounted to ninety-five per cent. Two had fed upon terrestrial species only. Corixa made ninety-five per cent. of the food of one. One had fed solely upon filamentous Algæ, and ninety per cent. or more of the food of three others consisted of vegetable structures in general.

PHENACOBIUS SCOPIFERUS, Cope.

This species occurs not very abundantly throughout the State, from Galena to extreme Southern Illinois. It has been taken by us almost invariably in swift and shallow streams.

The mouth is small and inferior, provided with fleshy lips somewhat resembling a sucker's in form. The gill-rakers and pharyngeal teeth are as usual in this group and the intestine is contained once and a half in the length of the head and body.

The nine specimens studied were from five localities, distributed from Galena to Union county. The food was almost purely insects, only two per cent. being unrecognized vegetation. Seventy-six per cent. consisted solely of Chironomus larvæ, and six per cent. of case-worms. Adult chironomids, taken by two of the specimens, amounted to two per cent. A few Cyclops found in a single specimen were the only Crustacea eaten by these fishes.

The peculiar character of this food, almost precisely that of a darter, is evidently related to the habitat of the fish.*

SEMOTILUS CORPORALIS, Mitch. CHUB.

This is a widely distributed and very abundant fish, perhaps the commonest species in the small creeks; but is less abundant in lakes and ponds.

The head and mouth are unusually large for a minnow; the intestine is six-sevenths the length of the head and body; and the gill-rakers are of the usual form.

Twenty-two specimens, from widely separated localities, give a ratio of seventy-six per cent. of animal food, four per cent. being fishes (partly Cyprinidæ), thirteen per cent. vegetation, and three per cent. worms. Insects make a little over half the whole, about one-half of them terrestrial. No Chironomus larvæ were found in the food of these fishes. Of neuropterous larvæ only a trace occurred, aquatic Coleoptera were noted in two, and Corixa in one. Grasshoppers (Acrididæ) made ten per cent. of the whole and were eaten by three of the specimens. Five had taken crawfishes, which made twelve per cent. of the entire food. No Entomostraca were noted, with the exception of one per cent. of Cyclops

*For a discussion of this matter, see Bulletin 3 of this series, p. 25.

occurring in two of the specimens. Numerous examples of Gordius were found in two, and were reckoned at three per cent. of the food.* The vegetable food (twenty-four per cent.) was half Algæ, the remainder miscellaneous vegetable debris.

Eight had eaten only insects, two having filled themselves with grasshoppers. Three from a prairie stream near Normal had taken only crawfishes, while of four specimens captured in McLean County in July, filamentous Algæ composed ninety-four per cent. of the food.

CERATICHTHYS BIGUTTATUS, Kirt. HORNED CHUB.

This species is everywhere abundant northward, chiefly, like Semotilus, in the smaller streams, but preferring swifter waters. We have not taken it, however, south of the center of the State.

It differs from the preceding members of the group by the greater length of its alimentary canal, which considerably exceeds the head and body, the latter being contained in the intestine about one and one-fourth times. The gill-rakers are not peculiar.

Thirteen specimens from Northern and Central Illinois had derived less than half their food from the animal kingdom. Only about one-fourth of it consisted of insects, largely case-worms and other neuropterous larvæ, another fourth being Crustaceans (crawfishes), eaten, however, by only two of the specimens. The vegetable food (fifty-four per cent.) was about equally divided between filamentous Algæ and seeds of Setaria and other grass-like plants.

Notwithstanding the small ratio of insects figured out, it is worthy of note that two specimens out of four captured in a creek in September had eaten only insects, chiefly case-worms, while these composed ninety-five per cent. of the food of another. As the intestines of these fishes contained a considerable quantity of gravel, it is evident that they had fed upon the bottom in rather swift water. On the other hand, two specimens had derived all their food from vegetable sources, and three others had eaten eighty per cent. or more of vegetation. The extraordinary amount of vegetation in the food of this fish is possibly related to the increased length of the alimentary canal.

*These were not from the same specimens as those containing the grasshoppers.

Summary for the Group.

Ninety-five specimens of Group IV examined, representing five genera, had derived about three-fourths of their food from the animal kingdom, three per cent. of it being fishes, sixty-one per cent. insects, one per cent. Arachnida, and eleven per cent. Crustacea. One-third of the insects and spiders belong to terrestrial species. Chironomus larvæ are among the most important aquatic elements, amounting to sixteen per cent.; neuropterous larvæ coming next (eleven per cent.). About two-thirds of the crustaceans were crawfishes, the remainder being Cladocera and Copepoda. The vegetation (nearly one-fourth of the entire food) was chiefly of miscellaneous origin, nine per cent. only being recognizable as of aquatic forms. This was almost entirely filamentous Algæ.

Concerning this fourth group it may consequently be said, roughly, that the food consists of insects, crustaceans, and vegetable debris, about two-thirds of it the first, one-fourth of it the last, and one tenth, the other.

Summary for the Family.

If we regard the two hundred and fourteen specimens of fourteen genera which I have studied, as fairly representative of the family Cyprinidæ, and strike a separate balance of their food, we shall find that about thirty per cent. of the contents of the alimentary canal consists of mud; that one-half of it, or a little less, is animal matter, and that vegetation amounts to about one-fourth. Insects make one-third of the entire food, about ten per cent. being terrestrial species, eight per cent. Chironomus larvæ, and an equal number larvæ of Neuroptera. Of aquatic Coleoptera we have only a trace, and of aquatic Hemiptera (Corixa), but one per cent. Crustacea stand at ten per cent., nearly half of them Cladocera, Entomostraca as a whole amounting to about three-fourths of the crustacean ratio. Fishes are only two per cent., and mollusks less than one. Nearly half the vegetable food consists of Algæ (chiefly filamentous forms), the remainder being miscellaneous structures, derived from a great variety of plants, mostly terrestrial.

Summing up, in a word, the characteristics of the food of the family as thus indicated, we may say that about one-half of it consists of animal substances, one-third being insects, and one-third of these of terrestrial species, and ten per cent. being crustaceans; that one-fourth consisted of vegetation, about equally aquatic and terrestrial, and that the remainder is mud, probably containing more or less fluid organic matter.

Comparison of the Groups.

It will be remembered that the groups were based upon differences in the structures relating to the appropriation and mastication of food. It is consequently from a comparison of the ratios of these groups that we shall derive the most interesting facts relating to the correspondence of food and structure. The most conspicuous result is the great preponderance of mud in the intestines of the fishes of the first group, characterized by an extraordinarily elongate intestine, and by pharyngeal teeth destitute of hooks and provided with a broad grinding surface. Here, as already noted, mud, sand, and gravel amounted to about three-fourths of the matter ingested, while in the third and fourth groups only trivial and accidental quantities occurred. In the second group, on the other hand, with intestines intermediate in length, mud was still abundant, but much less so than in the first, averaging less than half the whole. If we exclude this indigestible matter, however, we shall find the first group still further distinguished by the predominance of vegetation as compared with animal matter, the latter being only about one-third the former, while in Groups III and IV, on the other hand, vegetation amounts to about one-third the animal food. The groups last mentioned, distinguished from each other as they are, only by the presence of a masticatory surface on the pharyngeal teeth in the first, and its absence in the second, differ scarcely at all in their general food characters, and this structural feature seems therefore to be of little significance. In both the animal ratio amounts to seventy-five per cent., and vegetation stands in each at twenty-five; while insects are respectively fifty and sixty-one. It is true that we find neuropterous larvæ greatly predominant in the first group, making one-fourth of their food, and Chironomus larvæ in the second amounting to sixteen per cent. The second of

these facts we find upon analysis to be evidently due to Phenacobius, by which genus nearly all the Chironomus larvæ were taken; and this, as already shown, is explained not by any structural feature, but by its peculiar habitat; and when we note that aquatic larvæ together amount in Group III to twenty-five per cent., and in Group IV to twenty-seven, we see that the significance of the difference mentioned disappears. A similar explanation is found of the difference in the ratios of Entomostraca,—that of the first group amounting to twenty per cent. and that of the second only to four. An examination of the tables shows that this predominance in the group first mentioned is nearly all traceable to Hemitremia, a very small fish with rather elongate gill-rakers.

The importance of these gill structures is still more clearly indicated, as already noticed, by the difference between Notemigonus and Chrosomus of the second group, and clearly far outweighs the structure of the teeth as an indication of the food habits of the fish.

The general conclusions reached may be thus briefly stated: An extraordinarily elongate intestine indicates the limophagous habit, rather than an especial preference for vegetable food. The length or number of the gill-rakers has much to do with the abundance of Entomostraca and other minute animal forms in the food of the fish, while the presence or absence of the terminal hook or the masticatory surface to the pharyngeal teeth is not thus far shown to have any sensible influence upon the general average of the food. Finally, a species may depart widely in food characters from those more nearly allied to it in structure, if its favorite haunts are peculiar.

TABLE OF FOOD: APHREDODERIDÆ TO UMBRIDÆ.

	Aphredoderus sayanus.	Potamocottus meridionalis.	Gasterosteidæ.	Labidesthes sicculus.	Fundulus diaphanus.	Zygonectes notatus.	Zygonectes inurus.	Zygonectes dispar.	Summary of Cyprinodontidæ.	Umbra limi.
No. of Specimens Examined	19	6	7	25	8	17	6	2	33	9
KINDS OF FOOD.	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.									
ANIMAL FOOD	.99	1.00	.75	1.00	.81	.90	.63	1.00	.70	.59
I. FISHES	.02	.27	....	.01	....	*	....	....	*	....
II. MOLLUSCA	....	....	....	.01	.02	.03	.42	*	.15	.05
Univalves	....	....	....	....	.02	.03	.42	*	.15	.05
Bivalves	....	....	....	.01	....	....	....	....	....	....
III. INSECTS	.91	.44	.44	.54	.37	.73	.18	*	.43	.14
Aquatic larvæ	.08	.36	....	....	....	....	....	....	....	....
1. *Hymenoptera*	....	....	....	.01	.04	.08	.02	....	.05	....
2. *Diptera*	.45	.01	.43	.46	.14	.21	.07	*	.14	*
Terrestrial	....	....	....	.30	.01	.02	....	....	.01	....
Brachycera	....	....	....	.04	....	.01	....	....	.01	....
Chironomidæ	....	....	....	.25	.01	.01	....	....	†	....
Aquatic (larvæ)	.43	....	.37	.05	.02	*	....	....	.01	....
Culicidæ	†	....	....	....	....	*	....	....	*	....
Corethra	.07	....	....	....	....	....	....	....	....	....
Chironomus	.36	....	.17	.05	.02	....	....	....	.01	....
Simulium	....	....	.20	....	....	....	....	....	....	....
3. *Coleoptera*	.11	....	....	....	.06	.17	....	....	.08	....
Terrestrial	.11	....	....	....	....	....	....	....	....	....
Aquatic larvæ	....	....	....	....	.03	.08	....	....	.04	....
Hydrophilidæ	....	....	....	....	....	.08	....	....	.03	....
Philhydrus	....	....	....	....	.03	.04	....	....	.02	....
4. *Hemiptera*	.02	....	....	.01	.02	.17	.08	*	.09	.03
Terrestrial	....	....	....	.01	.02	.05	.05	....	.04	....
Aquatic	....	....	....	....	....	.11	.01	*	.04	....
Corixa	.02	....	....	....	....	.10	....	*	.03	....
5. *Neuroptera* (larvæ)	.25	....	....	.06	.11	.03	.01	....	.05	....
Ephemeridæ	.14	....	....	....	.11	....	....	....	.04	....
Palingenia	.07	....	....	....	....	....	....	....	....	....
Odonata	....	....	....	.06	....	.03	....	....	.01	....
Agrion	....	....	....	.01	....	.03	....	....	.01	....
Libellulidæ	.11	....	....	....	....	....	....	....	....	....
Leptoceridæ	....	....	....	....	....	....	.01	....	†	....
6 *Thysanura* (Podura)	....	....	....	†	....	....	....	....	....	....
IV. ARACHNIDA	....	....	.01	.03	.02	.03	....	....	.02	*
Terrestrial	....	....	.01	.03	.02	.03	....	....	.02	....
Hydrachnidæ	....	....	....	†	†	....	....	....	†	*
V. CRUSTACEA	.04	.29	.30	.40	.21	.06	.03	*	.10	.13
1. *Amphipoda*	.03	....	....	....	.13	*	.02	....	.05	.03
2. *Isopoda* (Asellus)	.01	.29	....	....	....	....	....	....	....	....
3. *Cladocera*	....	....	.28	.24	.01	.02	†	*	.01	.06
Daphniidæ	....	....	.14	.23	....	.01	....	....	....	....
Lynceidæ	....	....	.14	.01	.01	†	....	*	....	....
4. *Ostracoda*	†	....	.01	....	.07	.02	....	....	.03	.04
5. *Copepoda*	†	....	.01	.16	....	.02	.01	....	.01	....
VI. VERMES (*Chætopoda*)	.02	....	....	....	....	....	....	....	....	....
VII. Protozoa	....	....	....	....	....	....	†	....	†	....
VEGETABLE FOOD	.01	....	.25	....	.19	.10	.37	....	.17	.41
Seeds	....	....	....	....	.18	.01	....	....	.05	....
1. *Endogens*	†	....	....	....	....	....	.34	....	.09	.33
2. *Algæ*	.01	....	.25	....	.01	.09	.03	....	.03	.08

TABLE OF FOOD OF CYPRINIDÆ.

KINDS OF FOOD.	Campostoma anomalum.	Pimephales promelas.	Hyborhynchus notatus.	Hybognathus nuchalis.	Summary of Group I.	Notemigonus chrysoleucus.	Chrosomus erythrogaster.	Summary of Group II.	Hybopsis hudsonius.	Hybopsis stramineus.	Luxilus cornutus.	Hemitremia heterodon.	Summary of Group III.	Minnilus atherinoides.	Photogenis analostamus.	Phenacobius scopiferus.	Semotilus corporalis.	Ceratichthys biguttatus.	Summary of Group IV.	Summary of Cyprinidæ.
No. of Specimens...	9	4	9	8	30	25	3	28	17	5	21	18	61	18	33	9	22	13	95	
	NUMBER OF SPECIMENS AND RATIOS IN WHICH EACH ELEMENT OF FOOD WAS FOUND.																			
ANIMAL FOOD	....	.27	...	....	.07	.35	†	.18	.69	.76	.62	.87	.73	.95	.71	.98	.76	.46	.77	.48
I. FISHES	....	....	....	....	.. .	....	....	....	.03	....	.14	...	.04	.03	....	....	.04	....	....	.02
II. MOLLUSCA	....	. ..	....	...	....	.14	....	.07	.01	....	....	†	†	....	†	....	....	....	....	....
Univalves	....	....	....	....	....	.14	....	.07	....	....		†	†	....	†	....	....	....	....	....
Bivalves	....	....	....	.. .	..	....	....	....	.01	....	....	....	†	....	....	....	....	....	....	....
III. INSECTS	†	.25	†	....	.06	.06	....	.03	.51	.66	.45	.29	.48	.67	.63	.98	.56	.24	.61	.34
Terrestrial	....	....	....	....	....	....	....	....	....	....	.03	....	.01	.02	*	....	....	....	.01	.10
Aquatic	....	....	....	....	....	....	....	....	....	....	.02	†	†	....	.01	....	.12	.03	.03	....
1. *Hymenoptera*	....	....	....	....	....	....	....	....	....	....	.02	....	.01	.05	.04	....	10	....	.04	....
2. *Lepidoptera*	....	.15	....	....	.04	.03	....	.01	....	....	†	....	†	.01	.05	....	.01	.03	.02	....
3. *Diptera*	†	.10	....	. .	.02	†	....	†	.03	.05	.04	.24	.09	.14	.26	.78	.08	.01	.25	....
Terrestrial	....	....	....	....	....	....	....	....	....	....	....	.01	†	.11	.18	02	†	....	.06	....
Chironomidæ	....	....	....	....	....	....	....	....	....	....	....	.01	†	....	....	.02	....	....	....	....
Aquatic (larvæ)	†	....	....	....	†	†	....	†	.03	....	....	.20	.06	.02	.06	.76	....	.01	.17	....
Chironomus	†	....	....	....	†	†	....	†	.03	....	....	.20	.06	....	.03	.76	....	.01	.16	.08
Simulium	....	....	....	....	....	....	....	....	....	....	....	....	....	.02	.02	....	....	....	....	....
4. *Coleoptera*	....	....	....	....	....	.02	....	.01	.18	....	.06	....	.06	.13	.02	..	.10	01	.05	....
Terrestrial	....	....	....	....	....	.02	...	.01	.18	....	.05	....	.06	.13	.01	...	.05	.01	.04	....
Carabidæ	....	....	....	....	....	....	....	....	....	....	....	....	....	.04	....	....	.01	....	.01	....
Aquatic	....	....	....	....	....	....	....	....	....	....	.01	....	†	....	....	....	.03	....	.01	†
Haliplus	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.02	....	.01	....
Gyrinidæ (larvæ)	....	....	....	....	....	....	....	....	....	....	.01	....	†	...	....	....	....	....	....	....
Hydrophilidæ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.01	....	†	....
5. *Hemiptera*	....	....	....	....	...	.01	....	.01	.01	. .	.02	....	†	.11	.10	....	.03	....	.05	....
Terrestrial	....	....	....	....	....	....	....	....	....	...	†	....	†	.05	.01	....	....	....	.01	....
Aquatic	....	....	....	....	...	.01	....	01	.01	....	.01	....	.01	.05	.08	...	.03	....	.03	.01
Corixa	....	....	....	....	....	....	....	....	....	....	.01	...	.01	....	.08	....	.03	....	.02	....
6. *Orthoptera*	....	....	....	....	....	..	....	....	....	....	....	....	....	....	....	....	.12	....	.02	....
7. *Neuroptera*	....	....	....	....	....	....	....	....	.28	.58	.10	.03	.25	.17	.10	14	....	.16	.11	.08
Larvæ	....	....	....	....	....	....	....	....	....	....	.04	....	.01	....	.01	08	...	.03	.02	....
Pupæ	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.03	....	....	....	.01	....
Ephemeridæ	....	....	....	....	....	....	....	....	.28	.48	.06	.03	.21	.10	.01	....	....	.01	.02	....
Phryganeidæ	....	....	....	....	....	....	....	....	....	.10	....	....	.03	.07	.05	.06	....	.12	.06	....
IV. ARACHNIDA	....	....	....	....	....	†	....	....	....	....	†	†	†	.02	.01	..	....	....	.01	....
V. CRUSTACEA	....	....	†	....	†	.15	†	.08	.13	.10	.03	.58	.21	.22	†	†	.13	.22	.11	.10
1. *Decapoda* (Crawfish)	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.12	.22	.07	....
2. *Amphipoda*	....	....	....	....	....	....	....	....	....	....	.03	.01	.01	....	....	....	....	....	....	....
3. *Cladocera*	....	....	....	....	....	.10	†	.05	.01	....	†	.36	.09	.15	†	....	....	....	.03	.04
Sididæ (Daphnella)	....	....	....	....	....	....	....	....	....	....	....	.01	†	....	....	....	....	....	....	....
Daphniidæ	...	....	....	....	....	.10	....	.05	....	....	....	†	†	.12	†	....	....	....	.02	....
Lynceidæ	....	....	....	....	....	*	....	*	.01	....	†	.35	.09	†	†	....	....	....	†	....
4. *Ostracoda*	...	....	†	....	†	*	....	*	.12	....	†	.04	.04	....	....	....	....	....	....	.01
5. *Copepoda*	....	....	....	....	....	.05	....	.03	....	.10	....	.17	.07	.07	†	†	.01	....	.01	.02
VI. VERMES	....	.02	....	....	.01	....	....	....	....	....	†	†	†	....	....	....	.03	....	.01	....
Lumbriculus	....	....	....	....	....	....	....	....	....	....	†	....	†	....	....	....	....	....	....	....
Naidæ	....	.02	....	....	.01	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Gordius	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	.03	....	.01	....
Rotifera	....	....	....	....	....	....	....	....	....	....	....	†	†	....	....	....	....	....	....	....
VII. PROTOZOA	†	....	....	....	†	....	....	....	....	....	....	†	†	....	....	....	....	....	....	....
VEGETABLE FOOD	.20	.01	.20	.25	.18	.50	.13	.31	.31	.24	.38	.11	.26	.05	.29	.02	.24	.54	.23	.23
Miscellaneous	.02	†	.15	. .	.09	.21	.02	.11	.10	.01	.05	.03	.05	.01	.06	.02	.10	.02	.04	...
1. *Fungi*	....	....	....	†	†	. .	†	†	....	....	†	...	†	....	....	....	....	....	....	....
2. *Algæ*	.18	.01	.05	.25	.09	.19	.09	.14	.11	....	.12	.01	.05	.01	.09	....	.12	.23	.09	.10
MUD AND GRAVEL	.75	.72	.80	.75	.75	.15	.87	.51	†	...	....	.02	.01	....	....	†	....	....	†	.29

THE FIRST FOOD OF THE COMMON WHITE-FISH.

(COREGONUS CLUPEIFORMIS, Mitch.)

BY S. A. FORBES.

In a very large lake the conditions of life are remarkably uniform. The volume of water remains, of course, nearly constant from season to season and from year to year, and the extremes of summer heat and winter cold have but a moderate effect upon the temperature of the lake as a whole. Consequently both plant and animal life exhibit there a regularity and stability which are in remarkable contrast to their fluctuations in smaller bodies of water and on the surrounding land. Not only do the relative numbers of individuals in the various species remain about the same, but the absolute number of each must necessarily change but little, as a rule.

Such a state of affairs is eminently favorable to an exact and *economical* balance of supply and demand, of income and expenditure, of multiplication and destruction, among the inhabitants of the lake. Here, every species of animal, whether predaceous or vegetarian, must find, in the surplus products of growth and reproduction among the species upon which it depends for food, a far more constant and unvarying supply for its needs than elsewhere; and the species fed upon must be subject to a far more regular drain upon their surplus numbers or unessential structures. Where there is little fluctuation there is little waste.

A system of life like this, running on with relatively even tenor for centuries, must of course be much less *flexible* than one where wide and violent fluctuation and continual reädjustment are the rule; and a species in any way deeply affected will here have within itself far less recuperative power than one which has been forced again and again — each year, perhaps — to rally against the most destructive attacks as the price of its continued

existence. Disturbances of the natural balance of life, of the primitive and spontaneous system of reäctions by which the different groups of organisms are related, will therefore be unusually serious and lasting; and where such disturbances result from human interference, as by the yearly capture of large numbers of any important fish, it is especially desirable that artificial means of compensation be taken to restore the disturbed balance as nearly as possible. Excessive loss will be made good by natural reäctions far more slowly than if it occurred to a pond or river species, accustomed, as most of the latter are, to fill up rapidly enormous gaps in their numbers.

On the other hand, to multiply *unduly* by artificial measures any species naturally abundant in such a lake, will have scarcely a less disturbing influence than to *diminish* its numbers in the same ratio. The relatively nice balance between the demand for food and food supply which here naturally obtains, is such that an extraordinary increase in a species must soon reäct to diminish greatly its food resources — a fact which will then take effect on the species itself, reducing it below its natural, original level; and if both excessive capture and excessive multiplication go on side by side we shall have this result finally aggravated to an extreme degree.

As fishes are caught before the end of their natural lives, but planted by the fish culturist when young, it is evidently the food of the young which will be first and most seriously affected by over-production. Only a part of the adults, perhaps a small fraction, will live a life of ordinary natural length, many being captured before they have attained even the average size; but a far greater number, perhaps nearly every one, must survive the earliest period and must consequently draw most heavily upon the earliest food resources of the species when these differ from those of the adult.

The above considerations are brought forward here to show the especial importance, to us, of a study of the system of natural interactions by which the animals of our great lakes affect each other, if we would avoid the necessarily injurious consequences of our own interference with the natural order there obtaining, and above all to show the extraordinary value of a knowledge of the food habits and food capital of the *young*. They apply perhaps

more forcibly to the white-fish than to any other species in the lakes; because this is for several reasons the most important purely fresh-water fish of the great lake region, and proves to have a distinctly different food when young from that upon which it is dependent later.

According to the recent census report,* more than twenty-one million pounds of white-fish were taken in the Great Lakes in 1879, valued at over three-quarters of a million of dollars, and representing nearly half the total sum derived from the lake fisheries of all kinds. These fisheries employ over five thousand men, and a fixed capital of one million three hundred and fory-six thousand dollars. When we reflect that this enormous drain upon the number of the species is necessarily, to a considerable extent, an addition to the natural tax levied upon it by its enemies other than man, we see that there must be an artificial supply provided, or the fisheries will gradually fail.

The importance of the knowledge of the food of so valuable a species needs no demonstration, especially when we consider that, consistently with what has been said above, it may not be difficult to overdo the work of propagation.

If the white-fish were to be multiplied indefinitely, without any attention to the character or abundance of its food supply, it would soon reach such a number that it must infringe upon its own food capital, diminish the average number of the animals upon which it depends for subsistence, and so finally indirectly cripple itself. Then the money and labor expended in its culture would be principally lost, and the last state of the species would be worse than the first. An acquaintance with the food of the young is especially necessary, because they are planted by the fish-culturist when, having already absorbed the egg-sac (the supply of food by which they are under natural conditions supported until they have time to scatter themselves widely through the water), they are in a peculiarly helpless condition, unable to wander far in search of subsistence, and compelled to find food speedily or perish. One would say, therefore, that their alimentary resources and habits should be well and thoroughly known, that the range, period and abundance of the organisms upon

*Census Bulletin No. 261, Sept. 1, 1881.

which they feed should be carefully determined, and that each locality where the young are deposited should be closely searched for the purpose of ascertaining whether their food species occur there at the time in sufficient quantity to prevent immediate starvation.

Previous studies of the food of young fishes of a variety of families, reported in the third Bulletin of this series, had showed that, with exceptions presently to be mentioned, the earliest food of all the families studied consisted almost wholly of various species of Entomostraca and some equally minute and delicate dipterous larvæ. When that paper was prepared, I had, however, no opportunity to study the food of the young of any members of the family Salmonidæ, to which the white-fish belongs, neither could I learn that any such studies had been made by others; and I could only infer the same fact with regard to this family from the general character of the results obtained by the study of the other groups. Even this inference, however, was rendered doubtful by the discovery that the youngest individuals of two of the toothless families (Catostomidæ and Cyprinidæ) were not strictly dependent upon the food elements above mentioned, but were likewise able to draw upon much smaller organisms, namely: the minutest Protozoa and unicellular Algæ; and as the adult white-fish is likewise destitute of teeth, it was not by any means certain that their young would not fall under the latter category. Upon looking up the literature of the subject, I found that although the food of the adult had been very well made out in a general way,* only two items had been published respecting the food of the young. In the report of the United States Fish Commission for 1872–3, an assistant commissioner, Mr. J. W. Milner, made some experiments on young white-fish hatched artificially, supplying them with a number of articles of food, in the hope of finding something suitable for their nourishment.

"A few crawfish," he says, "were procured and pounded to a paste, and small portions put into jar No. 1; the young fish ate it readily. They were fed at night, and the next morning every one of them was found to be dead. Jar No. 2 was supplied with bread crumbs, and the fish were seen to take small particles in

*Report of the U. S. Fish Commission for 1872–3, pp. 44–46.

their mouths; they did not die so suddenly. Jar No. 3 was supplied witn sweet cream, but no evidence was afforded that the occupants fed upon it. A quantity of rain-water was exposed to the rays of the sun for the purpose of generating minute forms of life, and a teaspoonful was poured into jar No. 4, morning and evening, in the hopes that their proper food was of this character. In jar No. 5 a variety of food was provided, dry, fresh beef, milk, boiled potato, and bread. The crumbs of bread and the scrapings from the beef were all that the fish were seen to take into their mouths. They died, one after another, very rapidly, and in a few days all were dead." He further remarks: "This difficulty of procuring a suitable food for the young white-fish has been the experience of the few fish-culturists who have hatched them."

With the hope of ascertaining the natural food of these fishes, a few specimens, representing young captured in the Detroit River, and others from the hatchery, were submitted by Mr. Milner to Mr. S. A. Briggs, a microscopist, of Chicago. Four examples were examined by Mr. Briggs, two from each of the above situations. Those from the hatchery contained nothing whatever, while those from Detroit River contained numerous specimens of two species of Diatomaceæ, viz., *Fragilaria capucina* and *Stephanodiscus niagaræ*. The only fact at that time known would consequently indicate that the earliest food of the species consisted of Diatomaceæ.

The white-fish, as is well known, lays its eggs in the open lake in autumn, the young not appearing until early in the following spring. At this cold and stormy season in the exposed situations where they are to be sought, it is practically impossible to find the young fish; a fact which rendered the study of their earliest food a subject of unusual difficulty. There seemed, in fact, no practicable way to reach satisfactory conclusions upon it except by experiment upon individuals artificially hatched.

In December, 1880, I made an arrangement, through the kindness of Prof. Baird, of the Smithsonian Institution, with Mr. F. N. Clark, superintendent of the U. S. fish hatchery at Northville, Mich., for a supply of young white-fish to be sent me at intervals from the hatchery under his control. The specimens furnished were taken from two lots. The fishes of one lot, hatched January 18, were kept in a tank in the hatchery, where they were supplied

with water from a spring, which had been cooled by exposure to the air in artificial ponds before entering the hatchery, in order to retard the development of the fry. The ordinary range of temperature in the tank, was from thirty-five to thirty-nine degrees. These fishes were fed daily with a paste made by grinding small amphipod crustaceans (Gammarus) in a mortar.

The second lot, hatched January 20, was kept, unfed, in a perforated tin box, in a rivulet flowing from a spring, about sixty feet from its source. The water had a uniform temperature of forty-seven degrees.

Those in the spring being in warmer water than the others, developed much more rapidly, and it was believed that the character and source of this water was such as to furnish them at least a small supply of such food as young fishes are accustomed to appropriate.

Ninety specimens were received from the hatchery February 9, at which time they were three weeks old. They were thirteen mm. (half an inch) in length by one in depth. The egg-sac was but partially absorbed in most of the lot, but in those most advanced was represented by an oil globule back of the head. The pectoral fins were well developed, but no trace of the ventrals had as yet appeared. The single median fin extended well in front of the vent, and forwards on the back nearly to the head. The opercles did not fully cover the gills. The most highly developed specimens — those whose gill-sacs had nearly disappeared — had, at a short distance on either side of the symphysis of the lower jaw, a sharp, strong, raptatorial tooth, curved backwards and slightly inwards. The base of this tooth was very broad, and the point acute and slender. At a point behind each of these teeth about half their distance from each other, was a second much smaller tooth, directed almost exactly inwards. The upper jaw was, however, wholly toothless.

These fishes were all passed under the microscope, after having been rendered transparent, but only four of them contained anything whatever; three a little dirt, and the fourth a minute fragment of the crust of the Gammarus, with which they had been fed.

Of one hundred and eleven specimens received February 17, seventeen had taken food. I dissected nine of these and found

fragments of Gammarus and nothing else. Ninety specimens from the same lot were examined February 25, and food was found in fourteen. Four of these had eaten Gammarus fragments; two, larvæ of gnats; one, a small Cypris, and eight contained small fragments of the leaves and stems of vascular plants, including a bit of a netted-veined leaf and a little piece of pine wood. Thirty-nine specimens, the last of the lot, were received March 15, and food was found in fourteen. I dissected nine of these, finding fragments of Gammarus in four, a larva of a gnat, a Chironomus larva, a larva of some undetermined fly, a minute vegetable fragment, a Cyclops, a Cypris, and an undetermined Entomostracan each in one. Three hundred and forty fry from the hatching house were examined in all, in forty-seven of which (fourteen per cent.) more or less food was discernible. Of the thirty-five dissected, eighteen had eaten Gammarus fragments; five, minute insect larvæ; four, Entomostraca, and eight, small particles of vegetation.

Only four lots were received from the spring, on the 9th, 14th, 17th, and 25th of February, after which all died of starvation. In the first hundred only one was found which had taken food, and this had eaten a trace of filamentous Algæ and a minute fragment of the parenchyma of some higher plant, with a few diatoms. But one of the second hundred contained even a trace of food, a minute quantity of some thread-like Alga, the cells of which still contained a little chlorophyll. In the third hundred likewise, food was found in but one. This consisted of a few particles of vegetable parenchyma, doubtless derived from the decaying plant structure in or around the water. In the third lot of only forty-two specimens, six showed traces of food, consisting almost entirely of a few filamentous Algæ (including a fragment of Oscillatoria) and a little vegetable parenchyma. Desmids and diatoms were observed in trivial numbers.

The total number received from the spring was two hundred and forty-two, of which but eight were found to have eaten anything (a little over three per cent. of the whole), and these had taken only Algæ and vegetable fragments.

An example of the water of the spring sent me contained many Algæ but no animals larger than rotifers. The water of the hatchery, being exposed in ponds of considerable size, afforded a

better opportunity for the development of animal life, to which fact was doubtless due the occurrence of insect larvæ and Entomostraca in the intestines of the fishes reared in it. The situation of the spring, on the other hand, was particularly unfavorable, as it was under the hatchery, and consequently in the dark.

The observations above described on the specimens kept in spring water, have but little value for the reason that evidently very little food was contained in the water flowing through their cage. The vegetation in the streams being chiefly filamentous Algæ and the number of Entomostraca apparently trivial, very little of either vegetable or animal food could reach the little prisoners. It is not surprising, therefore, that notwithstanding their greater age and the higher temperature of the water in which they were kept, a much smaller ratio of the specimens had taken food than of those captured in the hatchery. From the contents of their intestines we can only infer that these fishes, reduced to a desperate strait by starvation, will snatch at almost anything contained in the water. The result obtained by a study of those from the hatching house was more significant, but still unsatisfactory. It seemed to indicate that in confinement white-fish fry will feed upon both animal and vegetable structures to some extent, and that they can be induced to take minute fragments of the higher crustaceans, but not in sufficient quantity to keep them alive. The fact that animal food was more abundant than vegetable in this last lot, indicates nothing of their natural preference, since it was doubtless also more abundant in the water containing them.

More light was thrown upon the earliest food habits of these fishes by the discovery of raptatorial teeth upon the lower jaw, than by these dissections of their alimentary canals. All the families of fishes which I had previously studied whose young were provided with teeth were found strictly dependent at first upon Entomostraca and the minuter insect larvæ; while only those whose young were toothless fed to any considerable extent upon other forms. The discovery of teeth in the young white-fish, therefore, placed this species definately in the group of those carnivorous when young. The fact that the adult was itself toothless interfered in no way with this inference, because other toothless fishes (Dorsoma) whose young were furnished with teeth, had been found carnivorous at an early age.

The inconclusive character of the results thus far obtained, made it necessary to attempt to imitate more closely the natural conditions of the young when hatched in the lake. In February, 1881, I obtained, through the kindness of Mr. Clarke, twenty-five specimens of living young white-fish, saved from a lot which he was planting in the waters of Lake Michigan, off Racine, Wisconsin. I succeeded in conveying these to the laboratory without loss, and there kept them for several days in a glass aquarium and supplied them with an abundance of the living objects to be obtained by drawing a fine muslin net through the stagnant pools of the vicinity. These consisted of many diatoms and filamentous fresh-water Algæ, of two or three species of Cyclops, of *Canthocamptus illinoisensis*, and *Diaptomus sanguineus* among the Copepoda, and of two rather large Cladocera, *Simocephalus vetulus* and *S. americanus*. These little fishes were kept under careful observation for several days, the water in the aquarium being frequently aërated by pouring. Many of them had, however, been injured by handling, and eleven of the specimens died without taking food. It was soon evident that the larger Entomostraca (the Simocephalus, and even the Diaptomus), were quite beyond the size and strength of these little fishes, and that only the smaller Copepoda among the animals available, could afford them any food at first. These they followed about from the beginning with signs of peculiar interest, occasionally making irresolute attempts to capture them. Two days after their arrival, one of the young white-fish had evidently taken food, which proved, on dissection, to be a small Cyclops. During the next two days nine others began to eat, dividing their attentions between the Cyclops above mentioned and the Canthocamptus, and on the 22d two others took a Cyclops each and a third a Canthocamptus. One of these fishes contained still a large remnant of the egg-sac, showing that the propensity to capture prey must antedate the sensation of hunger. On the 25th the fourteenth and last remaining fish captured its Cyclops and was itself sacrificed in turn. As an indication of the efficiency of the raptatorial teeth, it may be worth while to note that I saw one of the smallest fishes make a spring at a Cyclops, catch it, give three or four violent wriggles, and drop it dead to the bottom of tank.

As a general statement of the result of the observations made

on these fourteen fishes, we may say that eight of them ate a single Cyclops each, that one took two, and another three of the same, that one took a single Canthocamptus, that two specimens captured two each of this genus, and that finally, a single fish ate Cyclops and Canthocamptus both. The final conclusion was a highly probable inference that the smallest Entomostraca occurring in the lake would prove to be the natural first food of the species.

In order to test this conclusion with precision, I arranged a similar experiment on a larger scale and under more natural conditions. Through the generosity of the Exposition company, of Chicago, I was allowed the use of one of the large aquarium tanks in the exposition building on the lake shore, and by the repeated kindness of Mr. Clarke, of Northville, Michigan, I was furnished with a much larger number of living white-fish. Five thousand fry were shipped to me in a can of water, but through unfortunate delays in changing cars at intermediate points, about two-thirds of these were dead when they reached my hands. Those living were immediately transferred to the tank, through which the water, taken from the city pipes, had already been allowed to run for several hours. As this water is derived from Lake Michigan at a distance of two miles from the shore, and had at this time the exact temperature of the open lake, the conditions for experiment were as favorable as artificial arrangements could well be made.

Sending a man with a towing net out upon the lake with a boat, or upon the remotest breakwaters, immense numbers of all organic objects in the water were easily obtained. After enclosing the exit of the tank with a fine wire screen, to prevent the escape of objects placed in it, we poured these collections of all descriptions indiscriminately into the water from day to day, thus keeping the fishes profusely supplied with all the various kinds of food which could possibly be accessible to them in their native haunts. From this tank one hundred fishes were taken daily and placed in alcohol for dissection and microscopic study, to determine precisely the objects preferred by them for food. These were examined at a later date, and all contents of the intestines were mounted entire as microscopic slides, and pemanently preserved. A careful study, was of course made of the organisms of the lake, as shown by the product of the towing net, and when the experi-

ment was finally ended, an equally careful examination followed of the living contents of the water of the tank at that time.

These fishes, like those previously described, had already reached the age and condition at which it is customary to "plant" them in the lake. The ventrals were still undeveloped, the egg-sac had nearly disappeared, the four mandibular teeth were present, and the median fin extended from the tips of the pectorals on the belly to a point opposite the middle of the same fins on the back. In most the egg-sac did not protrude externally, being reduced in some to a droplet of oil, but remaining in a few of a size at least as great as that of the head. The alimentary canal was of course a simple straight tube, without any distinction of stomach and intestine.

The sufferings of these fry in transit had doubtless weakened the vitality of the survivors, and although every care was taken to keep the water of the tank fresh and pure, about one-third of those remaining died during the progress of the experiment. The aquarium in which they were confined was built of glass, and had a capacity of about one hundred cubic feet. The temperature, tried repeatedly, stood at forty-two degrees Fah. A steady current of the water of the lake was maintained through this tank, entering through a rose, from which it fell in a spray, thus insuring perfect aération.

By far the greater part of the organic contents of the water of the lake, as shown by the product of the towing net, consisted of diatoms in immense variety, which formed always a greenish mucilaginous coating upon the interior of the muslin net. In this were entangled, a variety of rotifers, occasional filamentous Algæ, and many Entomostraca, the latter belonging chiefly to the genera Cyclops, Diaptomus, and Limnocalanus among the Copepoda, and to Daphnia among the Cladocera.

As the Entomostraca proved to be far the most important elements of this food supply, the particulars respecting them may be properly more fully given. The smallest of all was a Cyclops, then new, but since described by me under the name of *Cyclops thomasi*.* This little Entomostracan is only .04 inch long, by .011

*On some Entomostraca of Lake Michigan and Adjacent Waters. American Naturalist, Vol. XVI., No. VIII, August, 1882, pp. 640 and 649.

wide. The next in size, and by far the most abundant member of this group was a Diaptomus, likewise new, described in the paper just cited under the name of *Diaptomus sicilis.* This appears in two forms, one evidently young in the stage just preceding the adult. Full grown individuals were .065 inch long, by one-fourth that depth. The Limnocalanus was a much larger form, evidently preying, to a considerable extent, upon the two just mentioned. All the Cladocera noticed were *Daphnia hyalina*, an elegant and extremely transparent species, occurring likewise in the lakes of Europe. A single insect larval form (Chironomus) should likewise be mentioned in this connection, since it had about the same size and consistence of the Entomostraca, and was consequently equally available for food.

The specimens of each of the above species from a certain quantity of these collections were counted, in order to give a definite idea of their relative abundance in the lake. The Diaptomus numbered 225, the Cyclops 75, Limnocalanus 7, Daphnia 3, and Chironomus larvæ 1. It was a curious fact, however, that when the water was drawn off at the end of the experiment, more than half the Entomostraca were Limnocalanus; a fact partly to be explained by the predaceous habit of the latter, and partly by the facts relating to the food of the fishes themselves, which are presently to be detailed.

The fry were placed in the tank and supplied with their first food on the evening of the 12th of March. On the 14th, one hundred specimens were removed, and twenty-seven of these were dissected. Twenty were empty, but the remaining seven had already taken food, all Cyclops or Diaptomus. Three had eaten Cyclops only, and six Diaptomus, while two had eaten both. Fourteen of these Entomostraca, seven of each genus, were taken by these seven fishes. From those captured the next day, twenty-five specimens were examined, of which nineteen were without food. Of the remaining six, three had eaten Diaptomus and three Cyclops; five of the former being taken in all, and ten of the latter. Three specimens were next examined from those caught on the 19th of March, two of which had devoured Diaptomus, and a third a single *Cyclops thomasi* and a shelled rotifer, *Anuræa striata.* The character of the food at these earliest stages was so well settled by these observations that I deemed it unnecessary to exam-

ine the subsequent lots in detail, but passed at once to the specimens taken on the 23d. Twenty-six of these were examined, and found to have eaten thirty-three individuals of *Cyclops thomasi*, fourteen of *Diaptomus sicilis*, and fourteen of the minute rotifer already mentioned (*Anuræa striata*). Two had taken a few diatoms (*Bacillaria*) and one had eaten a filament of an Alga. Cyclops was found in sixteen of the specimens, Diaptomus in nine, and Anuræa in eight, only two of them being empty. The amount of food now taken by individual fishes was much greater than before, one specimen dissected having eaten two Cyclops and six *Diaptomus sicilis*, male and female. Another had taken five Cyclops, one Diaptomus and five examples of *Anuræa striata*. Still another had eaten four of the Cyclops, four Diaptomus, and one Anuræa.

Twenty-five specimens were examined from those removed on the 24th of the month, at which time the water of the tank was drawn off and all the remaining fishes bottled. Four of these had not eaten, but the twenty-one others had devoured fifty specimens of *Diaptomus sicilis*, forty-seven of *Cyclops thomasi*, fourteen of *Anuræa striata*, and a single *Daphnia hyalina*, the latter being the largest object eaten by any of the fishes. A few examples of their capacity may well be given. The ninth example had eaten six Diaptomus, two *Cyclops thomasi* and one Anuræa; the tenth had taken eight Diaptomus, two Cyclops and an Anuræa; and the twentieth, seven Diaptomus and three *Cyclops thomasi*. In two of these examples were small clusters of orange globules, probably representing unicellular Algæ.

Summarizing these data briefly, we find that of the 106 specimens dissected, sixty-three had taken food, and that the ratio of those which were eating increased rapidly, the longer the fishes were kept in the aquarium. Only one-fourth of those examined on the fourteenth of the month had taken food, while more than five-sixths of those bottled ten days later had already eaten. The entire number of objects appropriated by these sixty-three fishes was as follows: *Cyclops thomasi*, ninety-seven; *Diaptomus sicilis*, seventy-eight; *Anuræa striata*, twenty-nine; *Daphnia hyalina*, one. Seven of the fishes had eaten unicellular Algæ, two had eaten diatoms, and one, filamentous Algæ.

From the above data we are compelled to conclude that the earliest food of the white-fish consists almost wholly of the smallest species of Entomostraca occurring in the lake, since the other elements in their alimentary canals were evidently either taken accidentally, or else appeared in such trivial quantity as to contribute nothing of importance to their support. In fact, two species of Copepoda, *Cyclops thomasi* and *Diaptomus sicilis*, are certainly very much more important to the maintenance of the white-fish in this earliest stage of independent life than all the other organisms in the lake combined. As the fishes increase in size, vigor, and activity, they doubtless enlarge their regimen by capturing larger species of Entomostraca, especially Daphnia and Limnocalanus.

A few words respecting the relative abundance of these species at different seasons of the year and their distribution in the lake, will have some practical value. We may observe here an excellent illustration of the remarkable uniformity of the life of the lake as contrasted with that of smaller bodies of water already referred to, in the introduction to this paper. While in ponds minute animal life is largely destroyed or suspended during the winter, the opening spring being attended by an enormous increase in numbers and rate of multiplication, in Lake Michigan there is but little difference in the products of the collecting apparatus at different seasons of the year.* There is a slight increase in the number of individuals during spring and early summer, but scarcely enough appreciably to affect the food supply of fishes dependent upon them. They are not by any means equally distributed, however, throughout the lake, my own observations tending to show that there are relatively very few of these minute crustaceans to be found at a distance of a few miles from shore, and that in fact by far the greater part of them usually occur within a distance of two or three miles out. Indeed, the mouths of the rivers flowing into the lake are ordinarily much

*For definite assurance of this fact, I am indebted less to my own observations (which are, however, consistent with it as far as they go) than to the statements of B. W. Thomas, Esq., of Chicago, who, while making a specialty of the Diatomaceæ of the lake, has collected and studied all its organic forms for several years, obtaining them from the city water by attaching a strainer to a hydrant many times during every month throughout the year.

more densely populated by these animals than the lake itself, as has been particularly evident at Racine and South Chicago. Neither are they commonly equally distributed throughout the waters in which they are most abundant, but like most other aquatic animals, occur in shoals. In the deeper portions of the lake, many species shift their level accordiug to the time of day, coming to the surface by night, and sinking again when the sun is bright.

These facts make it important to the fish-culturist that the particular situation where it is proposed to plant the fry should be searched at the time when these are to be liberated, to determine whether they will find at once sufficient food for their support. A little experience will easily enable one to estimate the relative abundance of the Entomostraca at any given time and place, and they require nothing for their capture more complicated or difficult of management than a simple ring net of cheese-cloth or similar material, towed behind a boat. This may be weighted and sunk to any desired depth, so that the contents of the water either at the surface or at the bottom, may be ascertained by a few minutes' rowing.

In conclusion, I wish again to express my great obligation to the United States Fish Commissioner, Prof. S. F. Baird, and to Frank N. Clark, Superintendent of the United States Hatchery at Northville, Mich., through whom, as already stated, the specimens were derived upon which these studies were made. My best thanks are also due to the Exposition company of Chicago, and especially to their secretary, the Hon. John P. Reynolds, for the use of a tank in the Exposition building, and for many courtesies received while the experiment there was in progress.

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*.