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		PAGE.
I.	On Some Interactions of Organisms........	3.
II.	The Food of Fishes: Acanthopteri.........	19.
III.	On the Food of Young Fishes.............	71.
IV.	The Food of Birds.......................	86.
V.	Notes upon the Food of Predaceous Beetles.	162.
VI.	Notes on Insectivorous Coleoptera.........	167.

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STUDIES

OF THE

FOOD OF BIRDS, INSECTS, AND FISHES

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ON SOME INTERACTIONS OF ORGANISMS.*

By S. A. FORBES.

While the structural relations of living organisms, as expressed in a classification, can best be figured by a tree,—the various groups, past and present, being related to each other either as twigs to twigs, as twigs to branches, or as branches to the main stem,—yet this illustration does not at all express their *functional* relations. While the anatomical characters of the various groups may show that they are all branches of a common stock, from which they have arisen by repeated divisions and continued divergencies, the history of their lives will show that they are now much more intimately and variously bound together by mutual interactions than are twigs of the same branch,—that with respect to their vital activities they occupy rather the relation of organs of the same animal body. If for a type of their classification we look to the vegetable world, for an illustration of their mutual actions and reactions we must look to the animal world. The serious modification of any group, either in numbers, habits, or distribution, must modify, considerably, various other groups; and each of these must transmit the change in turn, or initiate some other form of change, the disturbance thus propagating itself in a far-extending circle.

While the whole organic world, viewed as a living unit, thus differs from the single plant by the much greater in-

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*As details accumulated relating to the food of animals and similar subjects, it was found that a proper discussion of them would necessarily lead, step by step, to a full review of certain parts of the general subject of the reactions between groups of organisms and their surroundings, organic and inorganic. Without such a review, the facts can not be safely generalized, nor the conclusions clearly apprehended to which they point. It has therefore seemed best to prepare the way for the discussion of special subjects by this general discussion of the subject at large.

The practical importance of this larger view is illustrated by the fact that if the current ideas of the value of parasitic and predaceous insects are accepted, we must condemn the bluebird to extermination as a pest; while if the conclusions of this paper are essentially sound, this bird is a very useful species and should be carefully preserved.

terdependence of its parts, on the other hand, it differs from the single animal in the fact that, notwithstanding this intimate and instant sympathy of part with part, it has an immense vitality. To cut off the leg of an animal is often sufficient to destroy its life, but one might cut off the *head* of the animal world, so to speak, without seriously impairing its energy. Suddenly to annihilate every living vertebrate would doubtless set on foot some tremendous revolutions in the life of the earth, but it is certain that in time the wound would heal,—that Nature would finish by readjusting her machinery and would then go on much as before. In fact, any subkingdom of animals or any class of plants might thus be struck out, without the slightest danger that terrestrial life would perish as a consequence. The functions of the missing member would be taken on in part by other members, and in part be rendered needless by new adjustments.

We see many present illustrations of this fact, as in Australia, where there is but one native carnivorous animal, and that probably not indigenous; in several Pacific islands where mammals are unknown; and in New Zealand and the Galapagos, where insects are extremely few and the flowers, therefore, chiefly colorless and odorless. We see, likewise, illustrations of the same truth in the conditions of vegetable and animal life in earlier geological periods. Plants and insects, for example, existed together through vast periods of time when there were neither mammals nor birds on earth to supervise or regulate their relations.

If this is true of such immense and revolutionary disturbances, it is all the more certain that this same spontaneous action of natural forces must in time reduce the smaller disturbances of the primitive order caused everywhere by civilized man, and must end by adjusting the whole scheme of organic relations to his interests as completely as to the interests of any other species. It is also plain that if man understands clearly the disorders which arise in the system of Nature as a result of the rapid progressive changes in his own condition and activities, and understands also the processes of Nature which tend to lessen and remove these disorders, he may, by his own intelligent interference, often avoid or greatly mitigate the evils of his situation, as well as hasten their remedy and removal.

Some general notion of the original order of Nature, which obtains where civilization has not penetrated, will be needful for an understanding of the most important consequences of the modifications of that order which man brings to pass,—for an understanding of the relations of our own industrial operations and interests to the general laws and activities of the organic world under whose constant influence we must live and work.

There is a general consent that primeval nature, as in the uninhabited forest or the untilled plain, presents a settled harmony of interaction among organic groups which is in strong contrast with the many serious maladjustments of plants and animals found in countries occupied by man. This is so familiar a fact that I need not dwell upon it, but will cite the reader to the generally accessible "Introduction to Entomology," by Kirby & Spence, for a sufficient statement of it. It will be more to my purpose to discuss the subject from a different standpoint. To determine the primitive order of Nature by induction alone requires such a vast number of observations in all parts of the world, for so long a period of time, that more positive and satisfactory conclusions may perhaps be reached if we call in the aid of first principles, traveling to our end by the *a priori* road.

For the purposes of this inquiry I shall assume as established laws of life, the reality of the struggle for existence, the appearance of variations, and the frequent inheritance of such as conduce to the good of the individual and the species,—in short, the evolution of species and higher groups under the influence of natural selection. I shall also postulate, as an accepted law of Nature, the generalization that the species is maintained at the cost of the individual,—that, as a general rule, the rate of reproduction is in inverse ratio to the grade of individual development and activity; or, as Spencer tersely states this law, that "Individuation and Genesis are antagonistic." Evidently a species can not long maintain itself in numbers greater than can find sufficient food, year after year. If it is a phytophagous insect, for example, it will soon dwindle if it seriously lessens the numbers of the plants upon which it feeds, either directly, by eating them up, or indirectly, by so weakening them that they labor under a marked disadvantage in the struggle with other plants for foothold, light, air, and food. The interest of the insect is therefore identical with the interest of the plant it feeds upon. Whatever injuriously affects the latter, equally injures the former; and whatever favors the latter, equally favors the former. This must, therefore, be regarded as the extreme normal limit of the numbers of a phytophagous species,—a limit such that its depredations shall do no especial harm to the plants upon which it depends for food, but shall remove only the excess of foliage or fruit, or else superfluous individuals which must either perish otherwise, if not eaten, or, surviving, must injure their species by overcrowding. If the plant-feeder multiply beyond the above limit, evidently the diminution of its food supply will soon react to diminish its own numbers; a counter reaction will then take place in favor of the plant, and so on through an oscillation of indefinite continuance.

On the other hand, the reduction of the phytophagous insect below the normal number will evidently injure the food plant by preventing a reduction of its excess of growth or numbers, and will also set up an oscillation like the preceding, except that the steps will be taken in reverse order.*

I next point out the fact that precisely the same reasoning applies to predaceous and parasitic insects. Their interests, also, are identical with the interests of the species they parasitize or prey upon. A diminution of their food reacts to decrease their own numbers. They are thus vitally interested in confining their depredations to the excess of individuals produced, or to redundant or otherwise unessential structures. It is only by a sort of unlucky accident that a destructive species really injures the species preyed upon.

*See "Principles of Biology," by Herbert Spencer, Vol. II., pp. 397–478.

The discussion has thus far affected only such organisms as are confined to a single species. It remains to see how it applies to such as have several sources of support open to them,—such, for instance, as feed indifferently upon several plants or upon a variety of animals, or both. Let us take, first, the case of a predaceous beetle feeding upon a variety of other insects,—either indifferently, upon whatever species is most numerous or most accessible, or preferably upon certain species, resorting to others only in case of an insufficiency of its favorite food.

It is at once evident that, taking the group of its food-insects as a unit, the same reasoning applies as if it were restricted to a single species for food; that is, it is interested in the maintenance of these food-species at the highest number consistent with the general conditions of the environment,—interested to confine its own depredations to that surplus of its food which would otherwise perish if not eaten,—interested, therefore, in establishing a rate of reproduction for itself which will not unduly lessen its food supply. Its interest in the numbers of each species of the group it eats will evidently be the same as its interest in the group as a whole, since the group as a whole can be kept at the highest number possible only by keeping each species at the highest number possible.

If the predatory insect prefer some species of the group to others, we need only say that whatever interest it has in any species of the group, will be an interest in keeping up its numbers to the highest limit; and any failure in this respect will injure it in precisely the ratio of the value of that species as an element of its food. It would be most injured by anything injuriously affecting the species it most preferred—the *preferences* of animals being, according to the doctrine of evolution, like their instincts, inherited tendencies toward the things which have proved beneficial to their progenitors.

This argument holds for birds as well as for insects, for animals of all kinds, in fact, whether their food be simple or mixed, animal or vegetable, or both. It also applies to parasitic plants. The ideal adjustment is one in which the reproductive rate of each species should be so exactly adapted to its food supply and to the various drains upon it that the species preyed upon should normally produce an excess sufficient for the species it supports. And this statement evidently applies throughout the entire scale of being. Among all orders of plants and animals, the ideal balance of Nature is one promotive of the highest good of all the species. In this ideal state, towards which Nature seems continually striving, every food-producing species of plant or animal would grow and multiply at a rate sufficient to furnish the required amount of food, and every depredating species would reproduce at a rate no higher than just sufficient to appropriate the food thus furnished.

We must now point out how this common interest is naturally subserved,—how the mutually beneficial balance between animals and their food is ordinarily maintained.

Exact adjustment is doubtless never reached anywhere, even for a single year. It is usually closely approached in primitive nature, but the chances are practically infinite against its becoming really complete, and maladjustment in some degree is therefore the general rule. All species must oscillate more or less. Even the more stable features of the organic environment are too unstable to allow the establishment of any perfectly uniform habit of growth and increase in any species. The most unvarying species will at one time crowd its boundaries vigorously, and, at another, sensibly recede from them. That such an oscillation is injurious to a species may be briefly shown. The most favorable condition of a species is that in which its numbers are maintained at the highest possible average limit; and this, as already demonstrated, requires that its food supplies should likewise be maintained at the highest possible limit,—that the species should, in fact, confine its appropriations to the unessential surplus of its food. But when the numbers of an oscillating species are above this average limit, it will devour more than this surplus of its food,—its food supplies will be directly lessened. On the other hand, when the oscillating species falls below this limit, its food supplies, reacting, of course can not increase *beyond* the highest possible limit, but will reach it and there stop. The average amount of food will therefore be less than it might be if the species dependent upon it did not oscillate,—and, the food being less, the average number of the species itself must be smaller. Our problem is, therefore, to determine how these innumerable small oscillations, due to imperfect adjustment, are usually kept within bounds,—to discover the forces and laws which tend to prevent either inordinate increase or decrease of any species, and also those by which widely oscillating species are brought into subjection and reduced to a condition of prosperous uniformity. We may know in general that such laws and forces are constantly at work, and that the tendency of things is towards this healthful equilibrium, because we see substantially such an equilibrium widely established and steadily maintained through long periods of time, notwithstanding the great number and kaleidoscopic variability of the forces by which each species is impressed. But this idea will repay more detailed elucidation. We will notice, first, some of the checks upon injurious oscillations arising out of the laws of the individual organism, and afterwards those which are brought to bear upon it from without.

It will at once be seen that, in any case, the maladjustments possible are of only two kinds,—the rate of reproduction in the species must be either relatively too small or relatively too great. If it be relatively too small, if the species bring forth fewer young than could mature, on the average, under existing circumstances, whatever may be the oscillations arising, they will tend to disappear with the disappearance of the species. The average numbers of such a species being, in the most favorable event, less than they might be, it will be at a certain disadvantage in the general struggle for existence,—it will eventually yield to some more prolific species with which it comes in competition. If, for any reason, its rate of multiplication be or become too high, the law of the antagonism between individuation and genesis will constantly tend to bring it within the proper limit. Reproduction being more active than is necessary, the individual force and activity will be less than it might be,—the species will be at a disadvantage in the search for food, and in all its other activities, as compared with other species more exactly adjusted, or, as compared with members of its own species which tend to a better adjustment. As soon as a better-adjusted competitor appears, the other must begin to suffer, and in the long course of evolution will almost certainly disappear. The fact of survival is therefore usually sufficient evidence of a fairly complete adjustment of the rate of reproduction to the drains upon the species.

For the sake of illustration, let us take an instance—and the most difficult we can find for the application of these ideas,—the case of a caterpillar and its hymenopterous parasite.

If the rate of increase of the parasite be relatively too great, that is, if more parasites are produced than can find places of deposit for their eggs in the bodies of the mere *excess* of caterpillars, some of them will deposit their eggs in caterpillars which would otherwise come to maturity,—that is the number of caterpillars will be gradually diminished. With this diminution of their hosts the parasites will find it more and more difficult favorably to bestow all their eggs, and many of them will fail of development. The multiplication of the parasites will thus be checked, and their numbers will finally become so far reduced that less than the then excess of caterpillars will be infested by them, in which case the caterpillars will commence to increase in numbers, and so on indefinitely. Briefly, the excessive rate of increase of the parasite will keep up an oscillation of numbers in both parasite and host which will cross and recross a certain average line.

Let us now look at the method by which Nature may check this injurious fluctuation.

Let us suppose two groups of a parasitic species at work on the same species of caterpillar, of which one (A) is distinguished by a tendency to an excessive reproductive rate, while the other (B) multiplies no faster than is consistent with the best interest of its host. A, producing more eggs than B, must either parasitize more caterpillars than B, or must deposit a greater number of eggs in each. It can not parasitize more caterpillars than B, because this would require greater activity,—a higher individuation,—

and this is contrary to the law that individuation and genesis are antagonistic. Instead of being more active than *B*, it will then be less active, and will, therefore, deposit more eggs in each caterpillar. *B*, however, can not have acquired the habit of depositing too few eggs in each caterpillar, as that would compel it to search habitually for a greater number of larvæ than necessary,—to have acquired, that is, a habit of wasting energy,—which is, as already said, contrary to evolution. *A* will, therefore, sometimes deposit too many eggs in a caterpillar, and will then either lose the whole deposit, or bring forth a weakened offspring, which will, in the long run, give way to the more vigorous progeny of *B*. This regular production of a wasted excess will constitute an uncompensated drain upon variety *A*, which will end, like any other radical defect, in its yielding to its better-adjusted rival.

Or if, notwithstanding the foregoing, we suppose this excessive reproductive rate to have become fully established, then the parasite-ridden species will evidently labor under such a disadvantage in the struggle for existence that it will probably be crowded out, in time, by some more fortunate rival. If the pair are permanently ill-adjusted, so that permanent loss of numbers follows, they will be treated by the laws of natural selection as a single imperfect animal,—they will be pushed to the wall by some better-adjusted caterpillar and parasite, or by some insect free from troublesome companions. We may be sure, therefore, that, as a general rule, in the course of evolution, only those species have been able to survive whose parasites, if any, were not prolific enough sensibly to limit the numbers of their hosts for any length of time.

We notice incidentally that it is thus made unlikely that an injurious species can be exterminated, can even be permanently lessened in numbers, by a parasite strictly dependent upon it,—a conclusion which remarkably diminishes the economic role of parasitism. The same line of argument will, of course, apply, with slight modifications, to any animal or even to any plant dependent upon any other animal or any other plant for existence.

From the foregoing argument we conclude that, since the interest of a species of plant or animal and the interest of its "enemies" are identical, and since the operations of natural selection tend constantly to bring about an adjustment of the species and its enemies which shall best promote this common interest therefore *the annihilation of all the established "enemies" of a species would, as a rule, have no effect to increase its final average numbers.* This being a general law, applying to all organisms, it is plain that the real and final limits of a species are the *inorganic* features of its environment—soil, climate, seasonal peculiarities, and the like.

In treating of the external forces brought to bear upon an oscillating species to restrain its disastrous fluctuations, I shall mention only a part of the organic checks to which it is subject.

It is a general truth, that those animals and plants are least likely to oscillate widely which are preyed upon by the greatest number of species, of the most varied habit. Then the occasional diminution of a single enemy will not greatly affect them, as any consequent excess of their own numbers will be largely cut down by their other enemies, and especially as, in most cases, the backward oscillations of one set of enemies will be neutralized by the forward oscillations of another set. But by the operations of natural selection, most animals are compelled to maintain a varied food habit,—so that if one element fails, others may be available. Thus each species preyed upon is likely to have a number of enemies, which will assist each other in keeping it properly in check.

Against the uprising of inordinate numbers of insects, commonly harmless but capable of becoming temporarily injurious, the most valuable and reliable protection is undoubtedly afforded by those predaceous birds and insects which eat a *mixed food*, so that in the absence or diminution of any one element of their food, their own numbers are not seriously affected. Resorting, then, to other food supplies, they are found ready, on occasion, for immediate and overwhelming attack against any threatening foe. Especially does the wonderful locomotive power of birds, enabling them to escape scarcity in one region, which might otherwise decimate them, by simply passing to another more favorable one, without the loss of a life, fit them, above all other animals and agencies, to arrest disorder at the start,—to head off aspiring and destructive rebellion before it has had time fairly to make head. But we should not therefrom derive the general, but false and mischievous, notion, that the indefinite multiplication of either birds or predaceous insects is good. Too many of either is nearly or quite as harmful as too few.

And this brings us to the application of these principles to the interests of civilized man. We must note how the new forces which he brings into the field expend themselves among those we have been studying, and to what reactions they are in turn subjected. We must first see how far the primitive natural order of life lends itself to the supply of man's needs, to the accomplishment of his purposes; and must determine, in a general way, where he may be content to leave it undisturbed, where he should address himself to its improvement, and where he is compelled to attempt wholly to set it aside, substituting artificial arrangements of his own, devised solely in his own interest.

Some of Nature's arrangements man finds himself unable to improve upon for his own benefit. No one thinks of cultivating the forest to hasten the growth of the wood, or of trimming the wild oak or the maple, or of planting artificially the nuts and acorns in the woods to increase the number of the trees.

We are content to leave things there to go on essentially in the old way, merely anticipating the processes of natural death and decay by removing the trees before they spontaneously perish, and glad if the revolutions of organic life which we set up in the country around do not penetrate to the forest, visiting the leaves and trunks of the trees with the scourge of excessive insect depredations.

Usually, however, we find the ready-made system of Nature less to our liking, and all our cultures are attempts to set it aside more or less completely. In the pasture and meadow, it answers our purpose to substitute other species for the grasses growing there spontaneously, and these adapt themselves easily to the circumstances which have proved favorable to their native predecessors. But in the grain-field and fruit-garden the case is different. Not only do we bring in species often very unlike any aboriginal vegetation and still further altered by long cultivation, but we propose an end quite different from that for whose accomplishment all the arrangements of Nature have been made.

According to the settled order, the whole economy of every fully-established plant and animal is directed to the production of one more plant or animal to take the place of the first one when it perishes. All the excess of growth and reproduction is a reward to friends or a tribute to powerful enemies, intended to make only this one end secure. But man is not content with this. He does not raise apple-trees for the sake of raising more apple-trees. He would cut off all excess not useful to himself, and all that is useful he would stimulate to the utmost, and appropriate to his own benefit. In carrying out this purpose he finds himself opposed and harassed at every step by rules and customs of the natural world established long ages before he was seen upon the earth,—laws certainly too powerful for him wholly to defy, customs too deeply rooted for him to overturn without the most complicated consequences. And yet even here, we see that the primitive order is not an evil, it is simply insufficient. It is good as far as it goes, and must be carefully respected in its essence, however far it may be modified in detail. We find abundant reason for a belief in its usual beneficence and for a reluctance to disturb it without urgent necessity.

At the best the disturbances we must originate will be tremendous. Old combinations will necessarily be broken up and new ones entered into. As in a country undergoing a radical change in its form of government, disorders will almost certainly break out,—some of them fearfully destructive and temporarily uncontrollable; but the general tendency towards a just equilibrium will make itself felt, and intelligent effort will mitigate some evils and avoid others. Without attempting to go into details,—which would be quite unnecessary for my purpose,—I will endeavor briefly to show the bearing of some of these ideas upon practical conduct.

To man, as to nature at large, the question of adjustment is of vast importance, since the eminently destructive species are the widely oscillating ones. Those insects which are well adjusted to their environments, organic and inorganic, are either harmless or inflict but moderate injury (our ordinary crickets and grasshoppers are examples); while those that are imperfectly adjusted, whose numbers are, therefore, subject to wide fluctuations, like the Colorado grasshopper, the chinch-bug and the army-worm, are the enemies which we have reason to dread. Man should then especially address his efforts, first, to prevent any unnecessary disturbance of the settled order of the life of his region which will convert relatively stationary species into widely oscillating ones; second, to destroy or render stationary all the oscillating species injurious to him; or, failing in this, to restrict their oscillations within the narrowest limits possible.

For example, remembering that every species oscillates to some extent, and is held to relatively constant numbers by the joint action of several restraining forces, we see that the removal or weakening of any check or barrier is sufficient to widen and intensify this dangerous oscillation; may even convert a perfectly harmless species into a frightful pest. Witness the maple bark-louse, which is so rare in natural forests as scarcely ever to be seen, limited there as it is by its feeble locomotive power and the scattered situation of the trees it infests. With the multiplication and concentration of its food in towns, it has increased enormously, and if it has not done the gravest injury it is because the trees attacked by it are of comparatively slight economic value, and because it has finally reached new limits which hem it in once more.

We are therefore sure that the destruction of any species of insectivorous bird or predaceous insect is a thing to be done, if at all, only after the fullest acquaintance with the facts. The natural presumptions are nearly all in their favor. It is also certain that the species best worth preserving are the mixed feeders and not those of narrowly restricted dietary (parasites, for instance),—that while the destruction of the latter would cause injurious oscillations in the species affected by them, they afford a very uncertain safeguard against the *rise* of such oscillations. In fact, their undue increase would be finally as dangerous as their diminution.

Notwithstanding the strong presumption in favor of the natural system, when we remember that the purposes of man and what, for convenience' sake, we may call the purposes of Nature do not fully harmonize, we find it incredible that, acting intelligently, we should not be able to modify existing arrangements to our advantage,—especially since much of the progress of the race is due to such modifications made in the past.

We should observe, in passing, that the principal general problem of economic biology is that of the discovery of the laws of oscillation in plants and animals, and of the methods of Nature for its prevention and control.

For all this, evidently, the first, indispensable requisite is a *thorough knowledge of the natural order*,—an *intelligently conducted natural history survey.* Without the general knowledge which such a survey would give us, all our measures must be empirical, temporary, uncertain, and often dangerous.

Next we must know the nature, extent, and most important consequences of the disturbances of this order necessarily resulting from human interference,—we must study the methods by which Nature reduces these disturbances, and learn how to second her efforts to our own best advantage.

But far the most important general conclusion we have reached is a conviction of the general beneficence of Nature, a profound respect for the natural order, a belief that the part of wisdom is essentially that of practical conservatism in dealing with the system of things by which we are surrounded.

Summary.

The argument and conclusions of this paper may be thus briefly recapitulated:—

We find a mutual interdependence of organic groups and a modifiability of their habits, numbers, and distribution, which brings them under the control of man. We also see that, after the most violent disturbances of their internal relations, a favorable readjustment eventually occurs. Starting with the general laws of multiplication and natural selection, it is first observed that every species of plant or animal dependent upon living organic food is interested to establish such a rate of reproduction as will, first, meet all the drains to which it is itself subjected, and still leave a sufficient progeny to maintain its own numbers, and, second, leave a sufficient supply of its own food-species to keep them undiminished, year after year. That is, we find that the interests of any destructive plant or animal are identical with the interests of its food supply.

This common interest of the organism and its organic food is continually promoted by natural selection, by which those that unduly weaken the sources of their own support are eventually crowded out by others with a better-adjusted rate of increase; but, because of the immense number, variability, and complexity of the forces involved, a complete adjustment is never reached. Whether the rate of multiplication of the food-producing species be relatively too great or relatively too small, the result is to cause an oscillation of numbers of both depredating species and its food. These oscillations of a species are both directly and indirectly injurious to it, and tend, in various ways, to diminish the average of its numbers, especially by lessening the general average amount of the food available for it. By the operations of natural selection, therefore, widely oscillating species, thus placed at a marked disadvantage as compared with more stable ones, are either eliminated, or else reduced to order more or less completely. They tend to become so adjusted to their food supplies as to appropriate only their surplus and excess.

Hence, as a general thing, the real limits of a species are not set by its organic environment, but by the inorganic; and the removal of the organic checks upon a species would not finally diminish its average numbers.

Among the external checks upon the oscillations of species of insects, the most important are those predaceous insects and insectivorous birds which eat a varied food, using most freely those elements of their dietary which are, for the time being, most abundant.

When we compare the results of the primitive natural order with the interests of man, we see that, with much coincidence, there is also considerable conflict. While the natural order is directed to the mere maintenance of the species, the necessities of man usually require much more. They require that the plant or animal should be urged to excessive and superfluous growth and increase, and that all the surplus, variously and widely distributed in nature, should now be appropriated to the supply of human wants. From the consequent human interferences with the established system of things, numerous disturbances arise,—many of them full of danger, others fruitful of positive evil. Oscillations of species appear, not less injurious to man than to the plants and animals more directly involved. Indeed, most of the serious insect injuries, for example, are due to species whose injurious oscillations have resulted from changes of the organic balance initiated by man.

To avoid or mitigate the evils likely to arise, and to adapt the life of his region more exactly to his purposes, man must study the natural order as a whole, and must understand the disturbances to which it has been subject. Especially he must know the forces which tend to the reduction of these disturbances and those which tend to perpetuate or aggravate them, in order that he may reinforce the first and weaken or divert the second,

The main lesson of conduct taught us by these facts and reasonings is that of conservative action and exhaustive inquiry. Reasoning unwarranted by facts, and facts not correctly and sufficiently reasoned out, are equally worthless and dangerous for practical use.

THE FOOD OF FISHES.

By S. A. FORBES.

For a clear conception of the general and intricate interdependence of the different forms of organic life upon the earth, one can not do better than to study thoroughly the life of a permanent body of fresh water,—a river or smaller stream, or, better than these, a lake. The animals of such a body of water are, as a whole, curiously *isolated*,—closely related among themselves in all their interests, but so far independent of the life of the land about them that if every terrestrial plant and animal were annihilated it would doubtless be long before the general multitude of the inhabitants of the lake or stream would feel the effects of this event in any very important way.

Further, the greater difficulty of communication between the different parts of a water system as compared with the different regions of the land, is such that the former are much the more sharply limited. There is very much less interchange of all kinds between two branches of the same stream, for example, than between the tracts of land which they separate. Consequently, one finds in a single body of water a far more complete and independent equilibrium of organic life and activity than in any equal body of land. It forms a little world within itself,—a microcosm within which all the elemental forces are at work and the play of life goes on in full, but on so small a scale as to bring it easily within the mental grasp.

Nowhere can one see more clearly illustrated what may be called the *sensibility* of such an organic complex,—expressed by the fact that whatever affects any species belonging to it, must speedily have its influence of some sort upon the whole assemblage. He will thus be made to see the impossibility of studying any form successfully out of relation to the other forms,—the necessity for taking a comprehensive survey of the whole as a condition to a satisfactory understanding of any part. If one wishes to become acquainted with the black bass, for example, he will learn but little if he limits himself to that species. He must evidently study also the species upon which it depends for its existence, and the various conditions upon which *these* depend. He must likewise study the species with which it comes in competition, and the entire system of conditions affecting their prosperity. Leaving out any of these, he is like one who undertakes to make out the construction of a watch, but overlooks one wheel; and by the time he has studied all these sufficiently, he will find that he has run through the whole complicated mechanism of the aquatic life of the locality, both animal and vegetable, of which his species forms but a single element.*

In such a general survey of the plants and animals of a region, the study of their food relations will be found to afford an admirable objective point. Doubtless, of all the features of the environment of an individual, none affect it at the same time so powerfully, so variously and so intimately as the elements of its food. Even climate, season, soil, and the inorganic circumstances generally, influence an animal through its food quite as much as by their direct action. It is through the food relation that animals touch each other and the surrounding world at the greatest number of points, here they crowd upon each other the most closely, at this point the struggle for existence becomes sharpest and most deadly; and, finally, it is through the food relation almost entirely that animals are brought in contact with the material interests of man. Both for the student of science and for the economist, therefore, we find this subject of peculiar interest and value. It includes many of the most important relations of a species, and may prop-

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*I can not too strongly emphasize the fact—frequently illustrated, I venture to hope, by the papers of this series—that a comprehensive survey of our entire natural history is absolutely essential to a good *working knowledge* of those parts of it which chiefly attract popular attention,—that is, its edible fishes, its injurious and beneficial insects, and its parasitic plants. Such a survey, however, should not stop with a study of the dead forms of Nature, ending in mere lists and descriptions. To have an *applicable* value, it must treat the life of the region as an organic unit, must study it *in action*, and direct principal attention to the laws of its activity.

erly be made the nucleus about which all the facts of its natural history are gathered.

In a paper on the food of Illinois fishes published in the second bulletin of this Laboratory, the subject was treated in a general and cursory way, the amount of material upon which that paper was based being insufficient for exact or detailed description. The favor with which that preliminary notice was received, has made it possible to undertake a more serious investigation; and this paper contains an account of the food of the Acanthopteri of the state which I believe to be nearly or quite sufficient for the student of science and for the practical fish-culturist. It is still necessary only to study the food of specimens under a half-inch in length, and to test the value of the general conclusions here reached, by occasional examinations of fishes taken from other waters at other seasons of the year. Among the results of this study, those relating to the food of the young are especially worthy of attention, and these have therefore been summed up separately.

The explanation of certain structural conditions about the mouth, throat, and gills, has proceeded so far as to make it very likely that a number of definite general correspondences between structure and food will be made out, which will enable us to tell with considerable accuracy and detail what the food of an unknown fish must be, by a mere inspection of the fish itself; provided, of course, that we know what food is accessible to it in its habitat. It seems likely to prove to be a general rule that a fish makes scarcely more than a *mechanical* selection from the articles of food accessible to it, taking almost indifferently whatever edible things the water contains which its habitual range and its peculiar alimentary apparatus enable it to appropriate, and eating of these in about the ratio of their relative abundance and the ease with which they can be appropriated at any time and place. If this is so, knowing the structure of a fish and the contents of a body of water, we shall be able to tell, *a priori*, what the fish will eat if placed therein.

This is, in fact, the objective point of the present investigation,—to arrive at a knowledge of the correlations of structure and food habits sufficiently detailed and exact to make the tedious and difficult labor of examining the contents of stomachs unnecessary hereafter. Some generalizations of this sort are given in the following pages, and others relate to genera not included in this report.

The method of this paper differs from that of the previous one referred to by the calculation of the *ratios* of the different kinds of food for each species or group of individuals. These ratios were obtained by averaging careful estimates of the relative amounts of the different food elements found in each stomach.

It is proposed to follow a similar method hereafter down through the remaining orders of the class. Most of the material has been collected for this purpose, and much of it has been already studied.

Order TELEOCEPHALI.

Suborder ACANTHOPTERI.

This suborder includes all Illinois fishes which have the anterior dorsal fin (where there are two) or the first rays of the dorsal (where there is but one) stiff, spinous, and sharp, and united by an evident membrane; excepting only the remarkable "brook silversides," which is placed by Drs. Gill and Jordan in another group. It embraces all our game fishes except those belonging to the pickerel family (*Esocidæ*) and the salmon family (*Salmonidæ*). Its principal members are the darters, the various species of perch and bass, the sunfishes, and the sheepshead. Forty-six species of the order have been collected in the state, but only thirty-four of these are common enough to form features of any importance in our fish fauna.

The most numerous family of the group is the *Centrarchidæ* (sunfishes); the most important species are the two kinds of black bass, the pike-perch or "wall-eyed pike," *

*It is generally to be desired that the absurd names of "Salmon" and "Jack Salmon" for these species should be suppressed. They might as well be called suckers or catfishes or minnows, as far as accuracy is concerned. Common names are many times harder to kill than the cat of the proverb, however; and it is probable that unnumbered generations will continue to call the pike-perch "salmon"; the sunfishes, "perch"; and the black bass, "trout."

the common perch, the white bass, and the croppie or silver bass.

The following account of the food of this suborder is based upon the careful microscopic study of the contents of four hundred and twenty-five stomachs, representing six families, twenty genera * and thirty-three species.

These were all collected by myself or one of my assistants (Mr. W. H. Garman), and labeled at the time with name of species, locality, and date. While the northern half of the state is most fully represented, several trips to southern Illinois contributed to the material studied, and it is believed that the results arrived at are substantially true for our whole area.

Family ETHEOSTOMATIDÆ. The Darters.

What the humming-birds are in our avifauna, the "darters" are among our fresh-water fishes. Minute, agile, beautiful, delighting in the clear, swift waters of rocky streams, no group of fishes is more interesting to the collector; and in the present state of their classification, none will better repay his study. Notwithstanding their trivial size, they do not seem to be *dwarfed* so much as *concentrated* fishes —each carrying in its little body all the activity, spirit, grace, complexity of detail, and perfection of finish to be found in a perch or a "wall-eyed pike."

They are generally distributed, in suitable streams throughout the state; but we have found them much the most abundant in northern Illinois,—in the upper Galena River, in Yellow Creek near Freeport, and in tributaries of the Kishwaukee at Belvidere.

A short and strong minnow-seine of very fine mesh is needed in collecting them. Rapid hauls, made almost on the run, down stream, in swift and shallow water, will be found the most successful. Two or three species, of wider range, will be taken in ordinary situations, in collecting for minnows generally; but the brightest and most characteristic forms can only be got by special effort.†

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*The classification of this paper is substantially that of Jordan's Manual of the Vertebrates of North America, etc., Ed. 2, 1878.

†For a very entertaining and instructive account of these fishes, the reader is referred to papers in the American Naturalist, by Messrs. Jordan and Copeland, Vol. X., pp. 335–341, and Vol. XI., pp. 86–88.

I shall give here a description of the food of the family, based upon a study of the contents of seventy stomachs representing fifteen species, collected in all parts of Illinois, in several months of four successive years. These indicate much more than their number would imply, since from those collected at each time and place, as many were commonly studied as were necessary to give a full idea of the food of the species then and there. The different individuals from the same date and locality usually agreed so closely in food, that the study of from two to five gave all the facts obtainable from several times as many. The data here given, therefore, really exhibit the food of the family at different seasons in twenty-nine localities within the state.

The genus *Pleurolepis* is comparatively rare in Illinois, as there are few of the sandy streams in the state, which it inhabits. Seven individuals were examined—four of *P. pellucidus* and three of *P. asprellus*. The food of these specimens was remarkably uniform—the only elements found being the larvæ of small Diptera and ephemerids. Eighty-one per cent. of the food of all consisted of the larvæ of Chironomus,*—a small, gnat-like insect,—twelve per cent. of the larvæ of other small Diptera, and the remaining seven per cent. of ephemerid larvæ (May-flies).

Twelve specimens of the genus *Alvordius* were studied—seven of *maculatus* and five of *phoxocephalus*. These represented five different localities and dates. This is a larger species than the preceding, and to this fact is probably due the predominance (seventy-five per cent.) in its food of the larvæ and pupæ of May-flies (Ephemeridæ). These included four per cent. of the larvæ of *Palingenia bilineata*, Say, one of the largest ephemerids in our streams. The remaining kinds were larvæ of dragon-flies (Agrionidæ), four per cent., larvæ of Chironomus, seven per cent., *Corixa tumida*, Uhl., thirteen per cent., and Cyclops, one per cent.

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*The larvæ of Chironomus are among the most important elements of fish food in our waters, appearing in abundance in the stomachs of the young of a great variety of species. They have been too little studied in this country to allow specific determination.

The genus *Boleosoma*, regarded by Dr. Jordan as the typical darter, was represented by twelve specimens from eight localities—nine of *maculatum*, two of *olmstedi* and one of *camurum*.* These specimens show but slight food differences from other darters of similar size, the only notable variation being the appearance of fifteen per cent. of case-worms (larvæ of Phryganeidæ). Sixty-six per cent. of the food was Chironomus larvæ, seven per cent. larvæ of other minute Diptera, and the remaining twelve per cent. was larvæ of small ephemerids, and a few Cyclops.

I studied the food of two specimens of *Pœcilichthys variatus*, four of *P. spectabilis*, and two of *P. asprigenis*—making eight of the genus, representing six localities. Fifty-eight per cent. of small larvæ of Diptera (forty-nine per cent. of Chironomus), thirty-two per cent. of larvæ and pupæ of small ephemerids, and ten per cent. of case-worms made up the entire bill of fare.

Percina caprodes, the largest of the group, departs from all the foregoing species by the prominence given to crustacean food—thirty per cent. of Entomostraca and three per cent. of the smallest of our Amphipoda, *Allorchestes dentata*, (Smith) Faxon. Most of the Entomostraca were Cladocera, including Daphnia, Eurycercus, and Daphnella.†

Here occurred the only instance of molluscan food in the group. One specimen had taken a few individuals of *Ancylus rivularis*, Say. Reduced ratios of Chironomus and ephemerid larvæ, and a few *Corixa tumida* complete the list.

Of *Nanostoma zonale*, less common than the others, but two individuals were examined, and these had eaten nothing but larvæ of small Diptera, including sixty-five per cent. of Chironomus.

Six specimens of *Etheostoma flabellare* var. *lineolata*, from four localities, had eaten sixty-one per cent. of Chi-

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**Boleosoma maculatum* and *B. olmstedi* should undoubtedly be united. Specimens in the laboratory collection present the extremes of both forms, together with numerous intermediate stages of each character used to distinguish them.

This whole group exhibits a surprising variability, perhaps due to its comparatively recent origin.

†Daphnella was found in a Percina from the Calumet River, at South Chicago, but not in condition to permit the determination of the species.

ronomus larvæ, twenty-seven per cent. larvæ of small ephemerids, and twelve per cent. of Copepoda (Cyclops).

Boleichthys elegans, found only in the southern part of the state (three specimens examined), had eaten only dipterous larvæ (thirty-seven per cent.) and ephemerid larvæ (sixty-three per cent.). This is a larger, heavier species than most of the others, and, therefore, like Alvordius, prefers ephemerids to gnats.

Last and least comes *Microperca punctulata*, represented by nine specimens from four localities in northern Illinois. This smallest of the darters shares with Percina, the largest, the peculiarity of a large ratio of crustacean food, which made up sixty-four per cent. of the total. The principal kinds were Cyclops, Chydorus, young *Gammarus fasciatus*, Say, and young *Crangonyx gracilis*, Smith. The remaining elements were Chironomus larvæ (thirty-four per cent.) and a trace of ephemerids (two per cent.).

It will be seen that the family, taken as a whole, divides into two sections, distinguished by the abundance or deficiency of crustacean food. This is easily explained by the fact that Percina and Microperca range much more freely than the other genera, being frequently found among weeds and algæ in comparatively slow water with muddy bottom, while the others are rather closely confined to swift and rocky shallows.

In discussing the food of the whole group, taken as a unit, it may best be compared with the food of the young of other percoids. It is thus seen to be remarkable for the predominance of the larvæ of Chironomus and small Ephemeridæ—the former of these comprising forty-four per cent. and the latter twenty-three per cent. of the whole food of the seventy specimens. In young black bass (*Micropterus pallidus*), on the other hand, the averages of nine specimens, ranging from five eighths inch to one and a half inches in length, were, in general terms, as follows: Cladocera forty-two per cent., Copepoda seven per cent., young fishes twenty per cent., Corixa and young Notonecta twenty-nine per cent., and larval Chironomus only two per cent. The search for the cause of this difference leads naturally to an examination of the whole economy of these little fishes, and opens up the question of their origin as a group.

The close relation of the Etheostomatidæ to the Percidæ requires us to believe that the two groups have but recently diverged, if, indeed, they are yet distinctly separate.

We must inquire, therefore, into the causes which have operated upon a group of percoids to limit their range to such apparently unfavorable situations, to diminish their size, to develop unduly the paired fins and reduce the air-bladder, to remove the scales of several species more or less completely from the head, breast, neck, and ventral region, and to restrict their food chiefly to the few forms mentioned above.

No species can long maintain itself anywhere which can not, in some way, find a sufficient supply of food, and also protect itself against its enemies. In the contest with its enemies it may acquire defensive structures or powers of escape sufficient for its protection, or a reproductive capacity which will compensate for large losses, or it may become adapted to some place of refuge where other fishes will not follow. What better refuge could a harassed fish desire than the hiding-places among stones in the shallows of a stream, where the water dashes ceaslessly by with a swiftness few fish can stem? And if, at the same time, the refugee develops a swimming power which enables it to dart like a flash against the strongest current, its safety would seem to be insured. But what food could it find in such a place? Let us turn over the stones in such a stream, sweeping the roiled water at the same time with a small cloth net, and we shall find larvæ of Chironomus and small ephemerids and other such prey, and little else—food too minute and difficult of access to support a large fish, but answering very well if our immigrant *can keep down his size.* Here the principles of of natural selection assert their power. The limited supply of food early arrests the growth of the young; while every fish which passes the allowable maximum is forced for food to brave the dangers of the deeper waters, where the chances are that it falls a prey. On the other hand, the smaller the size of those which escape this alternative, the less likely will they be to attract the appetite of the small gar or other guerilla which may occasionally raid their retreat, and the more easily will they slip about under stones in search of their microscopic game.*

Like other fishes, the darters must have their periods of repose, all the more urgent because of the constant struggle with the swift current which their habitat imposes. Shut out from the deep still pools and slow eddies where the larger species lurk, they are forced to spend their leisure on or beneath the bottom of the stream, resting on their extended pectorals and anal, or wholly buried in the sand. Possibly this fact is correlated with the absence or rudimentary condition of the air-bladder; as it is a rule with many exceptions—but still, probably, a rule—that this organ is wanting in fishes which live chiefly at the bottom.

Doubtless the search for food has much to do with this selection of a habitat. I have found that the young of nearly all species of our fresh-water fishes are competitors for food, feeding almost entirely on Entomostraca and the larvæ of minute Diptera.† As a tree sends out its roots in all directions in search of nourishment, so each of the larger divisions of animals extends its various groups into every place where available food occurs, each group becoming adapted to the special features of its situation. Given this supply of certain kinds of food, nearly inaccessible to the ordinary fish, it is to be expected that some fishes would become especially fitted to its utilization. Thus the Etheostomatidæ as a group are explained, in a word, by the hypothesis of the progressive adaptation of the young of certain Percidæ to a peculiar place of refuge and a peculiarly situated food supply.

Perhaps we may, without violence, call these the mountaineers among fishes. Forced from the populous and fertile valleys of the river beds and lake bottoms, they have taken refuge from their enemies in the rocky highlands

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*In Boleosoma, which is normally scaled in front of the dorsal fin, we often find the skin of this region bare in large specimens, and showing evident signs of rubbing.

†Several of the Catostomidæ (suckers) are an exception to this rule, feeding when young chiefly on algæ and Protozoa.

where the free waters play in ceaseless torrents, and there they have wrested from stubborn nature a meager living. Although diminished in size by their continual struggle with the elements, they have developed an activity and hardihood, a vigor of life and glow of high color almost unknown among the easier livers of the lower lands.

The following table (see page 30) will facilitate a comparison of the records of the different genera. The percentages were obtained by estimating carefully the ratios of each element of the food of each individual, and averaging these ratios for all the individuals of a species.

Family PERCIDÆ. The Perches.

This family consists, in this state, of three species—the common yellow perch and the two species of pike-perch or "wall-eyed pike." I have examined the food of seventy-five specimens of this family, so distributed in time and space as to give a satisfactory idea of the usual food.

PERCA AMERICANA, Schrank. THE COMMON PERCH. RINGED PERCH.

This exceedingly well-known species is most abundant along the shores of Lake Michigan and in the small streams and lakes of the northeastern part of the state, becoming less common to the south and west. In the Illinois River at Peoria and Henry it occurs in limited numbers, but in southern Illinois disappears so completely that even its name (there generally pronounced "pearch") is transferred to a different family, the sunfishes (Centrarchidæ).

My knowledge of the food of this species is derived from the study of the contents of forty-nine stomachs, of which thirty were from adults and the remaining nineteen from fishes ranging from $\frac{13}{16}$ inch to four inches in length. Ten localities and as many dates are represented by these specimens. Some were taken in the Illinois River, others in Lake Michigan and its southern tributaries, and still others in Fox R. at McHenry, and in the lakes connected with that stream. One lot included in these notes was bought in the Chicago market. They were evidently of the river form of the species, and judging from the contents of their stomachs,

DETAILS OF THE FOOD OF THE ETHEOSTOMATIDÆ.

	Pleurolepis.	Alvordius.	Boleosoma.	Pœcilichthys.	Percina.	Nanostoma.	Etheostoma.	Boleichthys.	Microperca.
Number of specimens	7	12	12	8	11	2	6	3	9
I. MOLLUSCA	....	....	....	....	01	....	....	....	....
Ancylus rivularis Say	....	....	....	....	01	....	....	....	....
II. INSECTA	100	99	96	100	65	100	88	100	36
1. *Diptera*	93	07	73	58	43	100	61	37	34
Undetermined larvæ.	12	01	07	09	02	35	....	10	....
Chironomus larvæ ..	81	06	66	49	41	65	61	27	34
2. *Hemiptera*	....	13	....	....	05	....	....	....	....
Corixa	....	13	....	....	05	....	....	....	....
Undetermined	....	....	....	....	03	....	....	....	....
Larvæ	....	07	....	....	02	....	....	....	....
C. tumida Uhl.....	....	06	....	....	....	....	....	....	....
3. *Neuroptera*	07	79	23	42	17	....	27	63	02
Ephemeridæ........	07	75	08	32	09	....	27	63	02
Pupæ	....	08	....	14	....	....	....	....	....
Larvæ	07	63	08	18	09	....	27	63	02
Palingenia	....	04	....	....	....	....	....	....	....
Agrionidæ (pupæ) ..	....	04	....	....	...	....	....	....	....
Phryganeidæ (larvæ)	....	....	15	10	08	....	....	....	....
III. CRUSTACEA...	....	01	04	....	33	....	12	....	64
1. *Amphipoda*	....	....	....	....	03	....	....	....	12
Gammarus, yg.......	....	....	....	....	....	....	....	....	06
Crangonyx "	....	....	....	....	....	....	....	....	06
Allorchestes dentata Sm.	....	....	....	....	03	....	....	....	....
2. *Cladocera*............	....	....	....	....	24	....	....	....	27
Undetermined.......	....	....	....	....	05	....	....	....	....
Daphniidæ	....	....	....	....	06	....	....	....	....
Daphnia..........	....	....	....	....	07	....	....	....	....
Sididæ	....	....	....	....	05	....	....	....	....
Daphnella.........	....	....	....	....	05	....	....	....	....
Lynceidæ..........	....	....	....	....	01	....	....	....	03
Chydorus	....	....	....	....	...	....	....	....	24
Eurycercus........	....	....	....	....	01	....	....	....	....
3. *Ostracoda*............	....	....	....	....	01	...	....	....	....
Cyprididæ	....	....	....	....	01	....	....	....	06
Undetermined.....	....	....	....	....	01	....	....	....	06
Cypris	....	....	....	....	....	....	....	....	....
4. *Copepoda*	....	01	44	....	05	....	12	....	19
Cyclops	....	01	04	....	05	....	12	....	19
Confervoid Algæ...........	....	....	....	....	01	....	....	....	....

which included a crustacean* not known to occur in Illinois but found abundantly in Michigan, I conclude that they were from that state or from Wisconsin.

**Mancasellus tenax*, Harger.

Food of the Young.

Finding that the food of most fishes differs with age, I have grouped the young according to size, and averaged the food for each group separately,—the first group consisting usually of those under an inch in length, the second of those from one to two, etc.

Two perch under an inch in length had eaten nothing but Entomostraca—about equal quantities of Cyclops and Daphnias. It was not until the specimens reached an inch and a half in length that insects of any considerable size appeared in the food. A single smaller fish had eaten a a few minute larvæ of Chironomus, but otherwise the food at this age consisted wholly of Entomostraca.

About thirty-four per cent. of the food of nine specimens ranging from 1¼ to two inches in length consisted of insects, and sixty-six per cent. of crustaceans. The only insects recognized were the larvæ and pupæ of Chironomus (eleven per cent.), small water-bugs,—*Corixa tumida*, Uhl., *C. alternata*, Say, etc. (twenty-three per cent.),—and a trace of larvæ of May-flies (Ephemeridæ). The Crustacea were chiefly Cladocera and Copepoda—thirty-six per cent. and twenty-four per cent. respectively. Four of the nine had eaten small quantities of a small amphipod crustacean, *Allorchestes dentata*, which is very abundant north, and has, in fact, about the same distribution in the state as the perch itself. The Clădocera were chiefly Daphniidæ (twenty-seven per cent.), including *Daphnia pulex*, L., *Simocephalus americanus*, Birge, and *Bosmina longirostris*. Specimens of Chydorus and Pleuroxus made up the principal part of the nine per cent. of Lynceidæ eaten. The Copepoda were all Cyclops and Diaptomus.

Four specimens two and a half inches long, all taken at Peoria, in November, 1878, had eaten nothing but Hemiptera (twelve per cent.) and Neuroptera (eighty-eight per cent.). The Hemiptera were all *Corixa alternata*, and the Neuroptera were nearly all the extremely common larva of one of our most abundant May-flies (*Palingenia bilineata*, Say). Larvæ of small dragon-flies (Agrionini) made five per cent. of the food. The simplicity of the food of these specimens is probably due partly to the fact that they were all caught at the same time and place, and partly to the wintry weather when they were taken.

Four specimens, from three and a half to four inches long, representing two localities and dates, had eaten a greater variety of articles, the food, in fact, now closely approaching that of the adult. Forty-five per cent. of the food was insects,—chiefly larvae of May-flies,—and fifty-five per cent. Crustacea—chiefly Amphipoda and Cladocera. Other insect elements were larvæ of Chironomus, six per cent., and four per cent. of Corixas. The Cladocera were all Daphnia, and the Amphipoda were *Allorchestes dentata*. A single specimen from Long L., near Pekin, Ill., had eaten an isopod crustacean (Asellus). Cyprididæ, another family of minute crustaceans, formed eight per cent. of the whole food of these specimens.

Food of the Adult.

The thirty mature individuals may best be treated in two groups, the first from streams and the second from Lake Michigan.

Four of the first group were bought in the Chicago market, in March, 1880; six were taken from the upper Fox, in May; four were from Calumet R. at South Chicago, taken in August, 1878, and four were caught in October of that year, from the Illinois at Peoria.

We notice, first, the entire disappearance of Entomostraca, which are thus seen to be food proper to the young. We next observe the appearance of Mollusca (nineteen per cent.), which are evidently no insignificant food resource of the species. Unio, Cyclas, Succinea, *Physa heterostropha*, Say, and *Valvata tricarinata*, Say, are the mollusks recognized. Notwithstanding the lack of Entomostraca, Crustacea are the most important resource of these river specimens, constituting forty-eight per cent. of their food. Crawfishes (Cambarus) and our common little fresh-water shrimp (*Palæmonetes exilipes*, St.) compose ten per cent. of the whole; the previously noticed Allorchestes amounts to fifteen per cent.; and species of Asellus, and *Mancasellus tenax* to twenty-three per cent. The Mancacelli were all from the specimens from the Chicago market.

Insects are also an important item,—amounting to twenty-four per cent., nearly all being the larvæ of Neuroptera,—May-flies (Ephemeridæ), dragon-flies and case-flies (Phryganeidæ). A single specimen from Peoria Lake had eaten one small fish—a "darter" of the genus Pœcilichthys.

The second group, twelve specimens from Lake Michigan, presents a curious and instructive contrast in food to the foregoing. Mollusks and insects wholly disappear, and Crustacea are limited to the commonest crawfish of the lakes (*Cambarus virilis*, Hagen), which forms fourteen per cent. of the food. The remaining eighty-six per cent. consisted wholly of fishes, all minnows (Cyprinidæ) so far as recognized except one, and that was some undetermined percoid,—probably itself a perch.

It will thus be seen that the common perch has a food history of three periods,—the periods of infancy, youth, and mature age. In the first it lives wholly on Entomostraca and the minutest larvæ of Diptera; in the second, commencing when the fish is about an inch and a half in length, it takes up first the smaller and then the larger kinds of aquatic insects in gradually increasing ratio, the entomostracan food at the same time diminishing in importance; and in the third it appropriates, in addition, mollusks, crawfishes and fishes,—in the lake specimens depending almost wholly on the last two elements.

We have here the first instance of a fact which we shall see again and again illustrated,—that the young, having at first an alimentary apparatus too small and delicate to dispose of any insects but the minutest larvæ, live almost wholly on minute crustaceans.

It is proper to note that the lake and river perch are by some good authorities regarded as separate species,—the latter being much more highly colored than the former. I have not found so strict a separation of the two forms as that described by Mr. E. W. Nelson, but have frequently taken both in the same haul of the seine in different parts of Calumet R. and in Lake George, Ind.—a body of water communicating with Lake Michigan by an outlet three or four miles long. Occasional pale specimens are also taken far from the lakes, in the Fox and Illinois rivers. The difference in color is probably due partly to the smaller amount of light to which those inhabiting the deeper waters of the lake are exposed, and partly to their piscivorous habit combined with the comparatively few lurking-places afforded them. There is some evidence that fish food bleaches a fish directly, and a good deal that it does so indirectly, by increasing the importance of an inconspicuous appearance.

STIZOSTETHIUM CANADENSE, Smith. GRAY PIKE-PERCH. SAUGER. "JACK-SALMON."

Fourteen specimens of this excellent fish were examined, all of which were from the Illinois R., ten taken in October, 1878, one in June, 1877, and three in November, 1877. It is evidently a very destructive species. These specimens had eaten nothing but fishes. In three cases these were unrecognizable, and in two others I could only tell that they were Acanthopteri. Four of the remaining "pike" had eaten hickory-shad (*Dorysoma cepedianum*,) two had eaten catfish (Siluridæ) of which one was an Amiurus, two had eaten sheepshead (*Haploidonotus grunniens*), and one had taken a black bass and some sunfish (Centrarchidæ). The presence in the stomach of one of these fishes, of a catfish of medium size, with its poisonous pectoral and dorsal spines unbroken, was a striking illustration of the gastric energy of this species.

STIZOSTETHIUM VITREUM, Mitch. PIKE-PERCH. WALL-EYED PIKE. "SALMON."

This is far the finest of our river fishes,—second to no fresh-water species except, possibly, some of the salmon family. It occurs in the great lakes, and throughout the state generally in the larger streams. It is a much larger fish than the preceding, not infrequently reaching a weight of twenty pounds. Certainly no fish of our waters is better deserving of attention than this. The only drawback to its increase is in its voracity; but, although it devours an immense number of other fishes, there is no evidence that it is wantonly destructive or that it eats more in proportion to its weight than the black bass.

Twelve of this species were examined, two of which were under three inches in length, and the others adult.

Food of the Young.

A specimen two inches long, taken in the Illinois R., at Pekin, June 2, 1880, had eaten only a minute fish. One, two and a half inches long, taken at the same place in June, 1878, had also eaten a small fish and a few Entomostraca (Cyprididæ aud Daphniidæ). The appearance of these Entomostraca in the food of a fish of this size, makes it altogether probable that Stizostethium, like Perca, wholly depends on these minute Crustacea, when very young.

Food of the Adult.

The remaining specimens, taken from three localities, had eaten nothing but fishes, one-half of them only the hickory-shad or skip-jack (*Dorysoma cepedianum*). In one other specimen, this species was associated with a minnow (Cyprinidæ), and in still another with a small sunfish with three anal spines (Centrarchidæ). One of the remaining stomachs contained only an unrecognizable fish, and the the other two contained Cyprinidæ, including the creek chub, *Semotilus corporalis*.

The two species of this genus agree so closely in food that they may well be discussed together. Apart from their exclusively piscivorous habit, the most interesting fact shown is the importance of the hickory-shad as food for this fish. We shall find accumulating evidence that this shad, utterly useless for human food, is, notwithstanding, one of the most valuable fishes in our streams. Nevertheless, not the slightest attention is paid to its preservation, much less to its encouragement. The fishermen commonly regard these fishes as a mere nuisance, and leave them to die on the bank by hundreds, rather than take the trouble to return them to the water. They are a very delicate species, and are easily killed by rough handling in the seine, but the majority of those captured might be saved with a little care.

The abundance of these fishes as compared with some other species in the river might seem to indicate that they are common enough as it is. Few realize, however, the number of fishes needed to feed a pike-perch to maturity. Two or three items from my notes will furnish the basis for an intelligent estimate of this number.

From the stomach of a *Stizostethium canadense* caught in Peoria Lake October 27, 1878, I took ten well-preserved specimens of *Dorysoma*, each from three to four inches long; and from a *Stizostethium vitreum* I took seven of the same species, none under four inches in length. As the Dorysoma is a very thin, high fish, with a serrate belly, these were as large as a pike-perch can well swallow; and we may safely suppose that not less than five of this species would make a full meal for the pike-perch. The species is a very active hunter, and it is not at all probable that one can live and thrive on less than three such meals a week. The specimens above mentioned were taken in cold autumn weather, when most other fishes were eating but little; but, since fishes generally take relatively little food in winter, we will suppose that the pike-perch eats, during the year, on an average, at this rate per week for forty weeks, giving us a total *per annum* of six hundred Dorysomas destroyed by one pike-perch. We can not reckon the average life of a Stizostethium at less than three years, and it is probably nearer five. The smallest estimate we can reasonably make as to the food of each pike-perch would therefore be somewhere between eighteen hundred and three thousand fishes like Dorysoma. A hundred pike-perch, such as should be taken each year along a few miles of a river like the Illinois, would therefore require one hundred and eighty thousand to three hundred thousand fishes for their food. Finally, when we take into account that a number of other species also prey upon Dorysoma, and that the whole number destroyed in all ways must not exceed the mere *surplus* reproduced,—otherwise the species would be extinguished,—we can form some approximate idea of the multitudes in which the food species must abound if we would support any great number of predaceous fishes. Dorysoma, being a mud-eater and a vegetarian, taking animal food only during the entomostracan period, can probably be more readily maintained in large numbers in our muddy streams than any other fish.

It is evident that the increase of edible fishes without a corresponding supply of food will be largely time and labor thrown away. Probably if protected from wanton and ignorant destruction, the Dorysoma would abound sufficiently, as it is enormously prolific.

The following table is similar to that given for the preceding family. The mark † is used to indicate the occurrence of an element in too small an amount to figure in the ratios.

Table of the Food of the Percidæ.

	Perca.						
	One inch and under.	One to two inches.	Two to three inches.	Three to four inches.	River specimens.	Lake specimens.	Stizostethium.
Number of specimens examined.....	2	9	4	4	18	12	26
I. Fishes..................	....	....	....	....	06	86	100
Undetermined..................	....	....	....	....	....	50	23
Acanthopteri..................	....	....	....	....	....	08	21
Undetermined..................	....	....	....	....	....	08	08
Pœcilichthys..................	....	....	....	....	06	....	....
Centrarchidæ..................	....	....	....	....	....	....	05
Undetermined..................	....	....	....	....	....	....	03
Micropterus..................	....	....	....	....	....	....	02
Haploidonotus..................	....	....	....	....	....	....	08
Dorysoma..................	....	....	....	....	....	....	41
Cyprinidæ..................	....	....	....	....	....	28	09
Undetermined..................	....	....	....	....	....	28	05
Semotilus..................	....	....	....	....	....	....	04
Siluridæ..................	....	....	....	....	....	....	08
Undetermined..................	....	....	....	....	....	....	04
Amiurus..................	....	....	....	....	....	....	04
II. Mollusca..................	....	....	....	....	19	....	....
Physa heterostropha..........	....	....	....	†	05	....	....
Succinea..................	....	....	....	....	04	....	....
Valvata 3-carinata..............	....	....	....	....	01	....	....
Cyclas..................	....	....	....	....	05	....	....
Unio..................	....	....	....	....	04	....	....
III. Insecta..................	....	34	100	45	24	....	....
Pupæ..................	....	....	....	....	†	....	....
1. *Diptera* (larvæ)..................	....	10	....	06	01	....	....
Undetermined..................	....	01	....	....	....	....	....
Chironomus..................	....	09	....	06	01	....	....
2. *Hemiptera*..................	....	23	12	04	....	....	....
Corixa..................	....	23	....	04	....	....	....
Undetermined..................	....	11	....	04	....	....	....
C. alternata..................	....	....	12	....	....	....	....
C. tumida..................	....	12	....	....	....	....	....
3. *Neuroptera* (larvæ)..................	....	01	88	35	23	....	....
Ephemeridæ..................	....	01	83	35	08	....	....
Undetermined..................	....	....	....	35	03	....	....
Palingenia..................	....	....	83	....	05	....	....
Agrionidæ..................	....	....	05	....	04	....	....
Libellulidæ..................	....	....	....	....	08	....	....
Phryganeidæ..................	....	....	....	....	03	....	....

TABLE OF THE FOOD OF PERCIDÆ—Continued.

	PERCA.						
	One inch and under.	One to two inches.	Two to three inches.	Three to four inches.	River specimens.	Lake specimens.	STIZOSTETHIUM.
Number of specimens examined.....	2	9	4	4	18	12	26
IV. CRUSTACEA............	....	66	....	55	48	14	†
1. *Decapoda*..........	....	....	....	....	10	14	....
Cambarus..........	....	....	....	....	04	14	....
Palæmonetes..........	....	....	....	....	06	....	....
2. *Amphipoda*..........	....	06	....	24	15	....	....
Undetermined..........	....	02	....	....	....	....	....
Allorchestes..........	....	04	....	24	15	....	....
3. *Isopoda*..........	....	....	....	01	23	....	....
Asellus..........	....	....	....	01	11	....	....
Mancasellus..........	....	....	....	....	12	....	....
4. *Entomostraca*..........	100	60	....	30	....	....	†
Cladocera..........	55	36	....	22	...	....	....
Daphniidæ..........	55	27	....	22	....	....	†
Undetermined..........	55	13	....	....	....	....	†
Simocephalus..........	....	†	....	....	....	....	....
Daphnia..........	....	12	....	22	....	....	....
Bosmina..........	....	02	....	....	....	....	....
Lynceidæ..........	....	09	....	....	....	....	....
Undetermined..........	....	07	....	....	....	...	....
Pleuroxus..........	....	†	....	....	....	....	....
Chydorus..........	†	02	....	....	....	....	....
Copepoda..........	45	24	....	....	....	....	....
Cyclops..........	45	24	....	....	....	....	....
Diaptomus..........	....	†	....	....	....	....	....
Ostracoda (Cypris)..........	....	†	....	08	....	....	†
V. VEGETATION..........	....	....	....	....	03	....	....

Family LABRACIDÆ. The Bass.

We have but two species of this family, the white bass and the brassy bass (*Roccus chrysops* and *Morone interrupta*). As far as their food is concerned, these are evidently equivalent species, agreeing closely in their general relations, and differing only in their distribution.

Roccus chrysops, Raf. White Bass.

This species is of medium abundance throughout the northern half of the state,—most common in Lake Michigan. A curious fact of its distribution is its rarity in Fox River and the lakes connected with that stream. Indeed, during several days' active collecting in this region we did not see a single specimen, neither could we hear of the occurrence of the species in those waters, although we made careful inquiry for it among experienced fishermen.

My notes on its food relate only to eleven specimens, of which three, taken at South Chicago, in August, were young, but of unknown size. Two of these had eaten only Chironomus larvæ and the larvæ of a remarkable ephemerid? not yet determined, and the stomach of the third contained only a minute fish. The remaining eight individuals had depended chiefly on the larvæ of May-flies (sixty-nine per cent.). The other important articles of their food were twenty per cent. fishes (including one sunfish—Centrarchidæ) and eight per cent. isopod Crustacea (Asellus). Several attempts to secure food from Lake Michigan specimens were unsuccessful, as, being taken in pound-nets, their stomachs were always empty. Those studied were from various interior situations in the northern third of the state.

Morone interrupta, Gill. Striped Bass. Brassy Bass.

This fish replaces the preceding in the southern half of the state, the Illinois River forming a neutral zone between the respective territories of the two species.

The food of six specimens of this species was studied, all taken from the Illinois River from May to October.

Four of these were young. The smallest, one and a fourth inches long, taken at Peoria, in June, 1878, had eaten about equally of small *Dorysoma cepedianum* and Entomostraca—forty per cent. Leptodora and ten per cent. Cyclops. One, an inch and a half in length, taken at the same time and place, had eaten only Dorysoma, with a trace of Cyclops. The next, one and five-eighths inches in length, had eaten a small undetermined fish and a few Daphnias. The fourth, one and seven-eighths inches long, caught at Peoria, in October, had eaten only larvæ and pupæ of Chironomus.

The two adult specimens were feeding chiefly upon the larvæ of Neuroptera—especially May-flies. An *Allorchestes dentata* and a few small grasshoppers also appeared in the food.

It will be seen that this species apparently agrees closely with the preceding in its food. The large amount of crustacean food in the smallest specimen shows that we should probably find still smaller Labracidæ depending upon these as strictly as the Percidæ.

Family CENTRARCHIDÆ. The Sunfishes.

This interesting group, known, in some of its members, to every one who has ever seen a dozen fishes, is represented in Illinois by sixteen species, as the species of this family are now understood. The two black bass, included in this family for technical reasons, are, of course, the most important species. The rock bass, the croppie and the common sunfish (*Lepiopomus pallidus*), although not fishes of the first class, would be seriously missed if we were to lose them ; and boyhood in the country would be quite another thing if it were not for the "pumpkin-seed" in the mill-pond, whose barbaric splendor thrills the heart of the youthful fisherman as the more delicate beauties of the trout or salmon do those of tougher fibre.

I have studied the food of thirteen species of this group, as indicated by two hundred and thirty-seven specimens, well distributed in time and area.

Decided differences in food made out in the various genera, have been found to coincide with differences in a few structures about the mouth in such a way that one may predict, from an examination of these structures, what the leading peculiarities of the average food of any genus will be.

Micropterus pallidus, Raf. Large-mouthed Black Bass.

This famous species is too well known to require extended comment. The ordinary fishermen rarely distinguish it from the following; and, indeed, sportsmen do not always recognize the difference.

I have examined the food of thirty-one specimens of this species, fourteen of which were adults, and the remainder young, of different ages.

Food of the Young.

The first group, consisting of five specimens under one inch in length (ranging from $\frac{5}{8}$ to $\frac{3}{4}$ in.), represents three localities,—Crystal Lake, in McHenry county, the Illinois River at Pekin, Tazewell county, and the same stream at Starved Rock, in La Salle county. They were taken in June, July and August of three different years. It is evident, therefore, that the common features of their food can not well be attributed to any other fact than their similar size.

The entire food of these fishes consisted of small Crustacea,—all Entomostraca except seven per cent., eaten by a single fish, which consisted of the very young of some undetermined amphipod,—probably Allorchestes. Eighty-seven per cent. of the food was Cladocera, principally *Bosmina longirostris*, Müll. *Simocephalus americanus*, Birge, was also an important element; and traces appear of Chydorus, Pleuroxus and *Eurycercus lamellatus*. About six per cent. of Cyclops had been eaten.

In the food of the next group—six specimens, from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches long—minute fishes and insects appear. The fishes (twenty-nine per cent.) were not large enough to determine. The insects (forty-six per cent.) were mostly young water-bugs (Corixa), the principal part of which were about half grown. The adults were all *Corixa tumida*, Uhl. The Entomostraca drop to twenty-five per cent., about equally Cladocera and Cyclops. Among the former were many specimens of *Simocephalus americanus*, and a few of the rare and curious Leptodora mentioned in a previous paper.* The specimen in which this was found was taken at Peoria, in June, 1878. All of this group were taken from the Illinois River, but at different places and dates. Some, taken at the same place and time as others

*See Bull. No. 2, Ill. State Lab. Nat. Hist., p. 88.

of the preceding group, differed from them in the smaller number of Entomostraca eaten, and the larger number of insects,—differences evidently only to be explained as due to the different sizes of the fishes.

The next two specimens, between two and three inches long, had eaten only insects, chiefly *Corixa tumida*.

Four specimens, ranging from three to three and a half inches in length, all taken from a lake in the Illinois River bottom, in October, 1879, had eaten nothing but insects,—almost wholly Corixas and the larvæ of May-flies (Ephemeridæ). The Corixas were *C. alternata*, Say, and *C. tumida*, Uhl.

Food of the Adult.

Turning to the food of the fourteen adults, we note the total disappearance of Entomostraca, the merely accidental occurrence of insects, the appearance of crawfishes (*Cambarus immunis*), which amount to seven per cent. of the whole food, and the great predominance of fishes (eighty-six per cent.). These were of sufficient variety to show that no group is safe from the appetite of the bass unless it be the gar.

Perch, minnows, catfish and hickory-shad were recognizable. The last were much the most abundant, occurring in eight of the specimens, and constituting fifty-eight per cent. of the food of the whole number. They ranged from three to six in each stomach, and were from three to four inches long. It should be noted, however, that these were all eaten by fishes taken at the same place and time. A large mouse was found in the stomach of one bass from the Illinois River.

We may generalize these data by saying that this black bass lives, at first, wholly on Entomostraca; that it commences to take the smallest aquatic insects when about an inch in length, and that minute fishes appear in its diet almost as early. From this forward, the Entomostraca diminish in importance, and the insects and fishes become larger and more abundant in the food. The adults eat voraciously of a great variety of fishes,—especially the hickory-shad (Dorysoma),—and feed upon crawfishes also to some extent.

MICROPTERUS SALMOIDES, Lac. SMALL-MOUTHED BLACK BASS.

This species, called also tiger bass, river bass, etc., is the black bass *par excellence*. It ranges, usually, in deeper and clearer water than the preceding; but both are often taken together.

I have made full notes of the food of twenty-seven specimens—three adult and the others young. I had none of this species under an inch in length; but, judging from the general resemblance of the food of this and the preceding bass at later ages, I do not doubt that this will also be found to feed at first on Entomostraca, although insect food is possibly more important to it from the beginning.

Seven individuals, from one to two inches in length, were all taken in July from rocky ripples in the Fox River, at Dayton, Ill., a few miles above the mouth of the stream. These had eaten only five per cent. of Entomostraca,—the whole remainder of the food consisting of insects, of which *Corixa tumida*, young and adult, and larvæ of May-flies and darning-needles (Agrionidæ) were the most important kinds. Four per cent. of the larvæ of Chironomus are worthy of notice. The scarcity of Entomostraca in the food of fishes as small as these is probably due to the situation in which these specimens occurred, as few Entomostraca are to be found in swift water. The same fact will account for the presence of Chironomus larvæ,—found abundantly under stones in rapid streams.

The next ten specimens, between two and three inches long, were taken in July, partly at the same place as the preceding, and partly from the Illinois River, a few miles below the mouth of the Fox. These differed from the smaller specimens chiefly in the appearance of fishes in the food (five per cent.) and in the absence of Neuroptera. Probably the last of these differences, at least, was accidental. A few larvæ of aquatic Coleoptera (Hydrophilidæ and Dytiscidæ) were noticed. Corixas, including *C. tumida*, Uhl, and *C. signata*, Fieb.,* amounted to eighty-two per cent. of the food.

In those ranging from three to four inches in length (seven individuals), the fishes eaten rise to fourteen per cent., but the insects drop away to seven per cent., and

*Determined by Mr. Uhler.

the Crustacea rise to seventy-nine. Here, however, difference of locality interferes to prevent any satisfactory comparison with other ages,—as these specimens were all taken in August, from Calumet River, at South Chicago. This slow stream, clogged with Algæ and a great variety of other aquatic plants in midsummer, also swarms with Crustacea,—especially the little *Allorchestes dentata*. This species made sixty-three per cent. of the food of these specimens; and an undetermined species of Asellus, fourteen per cent. A few *Gammarus fasciatus* were also found. The insects were Corixa and larvæ of Agrionidæ.

It will be seen that, excepting the gradual increase of the number of fishes eaten, these data show no especial difference in the young of different ages. Smaller specimens and a larger number from a greater variety of situations, would be necessary to exhibit this difference.

The food of the young as a whole, apparently, does not differ essentially from that of the large-mouthed species, except in the probably greater importance of the insect element—especially Corixas, which in these twenty-four specimens amounted to fifty per cent. of the food—and the inferior importance of fishes.

This peculiarity is expressed in a slightly different manner in the food of the adult. The three specimens examined had eaten only fishes (*Noturus flavus* and *Percina caprodes*) and crawfishes (*Cambarus propinquus*),—thirty-eight per cent. of the former and sixty-two per cent. of the latter.

This is the first of several instances in which the ratio of fishes in the food of allied species and genera was found to correspond to the size of the mouth, being largest in those with the largest oral opening.*

*The frequency with which these two species of black bass are confounded makes it desirable that a single reliable character should be selected by which they can be invariably distinguished, whatever the age of the specimen. This character is afforded by the size of the scales, the small-mouthed species having the smaller scales. In this species there are eleven longitudinal rows of scales between the dorsal fin and the row of perforated scales running along the middle of the side, called the lateral line. In the large-mouthed species, there are never more than nine such rows. The young are easily distinguished by the longitudinal black stripe along the side of the large-mouthed bass, which is wanting in the young of the other species.

TABLE OF THE FOOD OF MICROPTERUS.

	M. PALLIDUS.					M. SALMOIDES.			
	Under one inch.	One inch to two.	Two to three inches.	Three to four inches.	Adults.	One inch to two.	Two to three inches.	Three to four inches.	Adults.
Number of specimens......	5	6	2	4	14	7	10	7	3
I. FISHES	....	29	....	....	86	....	05	14	38
Acanthopteri...............	....	....	....	....	15	....	....	....	....
Percina	....	....	....	....	....	....	....	....	13
Perca.................	....	....	....	....	08	....	....	....	....
Dorysoma	....	....	....	....	58	....	....	....	....
Cyprinidæ.................	....	....	....	....	06	....	05	....	....
Campostoma	....	....	....	....	06	....	....	....	....
Siluridæ..................	....	....	....	....	07	....	....	....	....
Noturus flavus	....	....	....	....	....	....	....	....	25
II. INSECTS.........	....	46	100	100	†	95	89	07	....
Undetermined larvæ	....	....	50	....	....	....	....	....	....
1. *Diptera* (larvæ)..........	....	02	....	....	....	04	05	....	....
Culicidæ..............	....	....	....	....	....	....	01	....	....
Chironomus	....	02	....	....	....	04	....	....	....
Muscidæ.	...	....	....	....	....	....	04	....	....
2. *Coleoptera* (larvæ).......	....	....	....	....	....	....	02	....	....
Dytiscidæ..............	....	....	....	....	....	....	02	....	....
Hydrophilidæ	....	....	....	....	....	....	†	....	....
3. *Hemiptera*	....	44	50	57	†	51	82	03	....
Terrestrial............	....	....	....	†	....	....	....	....	....
Zaitha................	....	....	....	....	†	....	....	....	....
Corixa	....	42	50	57	....	51	82	03	....
Notonecta	....	02	....	....	....	....	....	....	....
4. *Neuroptera* (larvæ)......	....	....	....	43	†	39	†	04	....
Ephemeridæ	....	....	....	43	....	28	†	....	....
Agrionidæ	....	....	....	....	†	11	....	04	....
III. CRUSTACEA.....	100	25	....	†	07	05	04	79	62
1. *Decapoda*	....	....	....	....	07	....	....	....	62
Cambarus,............	....	....	....	....	07	....	....	....	62
2. *Amphipoda*	07	....	....	....	....	....	....	65	....
Gammarus............	....	....	....	....	....	....	....	02	....
Allorchestes	....	....	....	....	....	....	....	63	....
3. *Isopoda* (Asellus).........	....	....	....	....	....	....	....	14	....
4. *Entomostraca*	93	25	....	....	....	05	....	....	....
Cladocera..............	87	14	....	†	....	05	04	....	....
Daphniidæ	26	12	....	†	....	05	04	....	....
Simocephalus......	18	06	....	....	....	....	....	....	....
Bosmina..........	60	....	....	....	....	....	....	....	....
Leptodora	....	02	....	....	....	....	....	....	....
Copepoda (Cyclops)....	06	11	....	....	....	†	†	....	....
IV. VEGETATION ...	....	....	....	....	....	....	02	....	....
Endogenous	....	....	....	....	....	....	02	....	....
Algæ.....................	....	....	....	....	†	....	†	....	....
MISCELLANEOUS.....	....	....	....	....	07	....	....	....	....

AMBLOPLITES RUPESTRIS, Raf. ROCK BASS.

This favorite and widely distributed species does not differ from the other fishes mentioned in respect to the food of the young. The smallest specimen examined, five-eighths of an inch long, contained only a few Cladocera (Pleuroxus). Another, three-fourths of an inch long, had eaten Daphnids (seventy-five per cent.), Cyclops (ten per cent.), and larvæ of Chironomus. A third, seven-eighths of an inch long, contained only minute fragments of a few larvæ of Neuroptera. These specimens were all taken from Fox River, in July, 1879. The remaining young of the year were living chiefly on Corixa (eighty-three per cent.), as were also the young of the year preceding (ninety per cent.), so far as could be judged from the food of two specimens, from three to four inches in length. Some land insects, ephemerids, water-beetles, and a few Allorchestes were also found in the food.

Four adult specimens, taken at Ottawa, on the 8th of July, had eaten some minute fishes (fifteen per cent.), a few water-beetles, including *Tropisternus limbatus*, over forty per cent. of Neuroptera larvæ, and about thirty per cent. of small crawfishes. The Neuroptera included Baëtis and other ephemerids (twenty per cent.), Agrionidæ and large Libellulidæ, and fifteen per cent. of case-flies (Phryganeidæ). Pond-weed (Potamogeton) found in two stomachs, had probably been taken accidentally.

CHÆNOBRYTTUS GULOSUS, C. & V. WIDE-MOUTHED SUNFISH.

This fine species is among the commonest of the family in the lakes and ponds of southern Illinois, where it is commonly known as the "goggle-eye."

The northern limit of its range, so far as known, is the Illinois River valley. In number and habitat it replaces in the south the *Eupomotis aureus* of the north; but this equivalence is only apparent, as the two species differ widely in food. From its size and abundance, it is no insignificant food resource.

Food of the Young.

My smallest specimens were from lakes in the Mississippi bottom, near Bird's Point, Missouri. Two of these, one inch long and under , taken in September, 1879, had eaten only *Bosmina longirostris* and Cyclops. Insect food first appears in specimens one and a half inches long. Eight specimens, between one and three inches long, six of which were taken from a lake in the Illinois bottoms, near Pekin, in October, 1879, and two from a lake in Kentucky, near Cairo, Illinois, had eaten about forty per cent. Entomostraca, thirty per cent. Neuroptera larvæ, and thirty per cent. Corixas and Diptera larvæ. *Daphnia pulex*, *Simocephalus americanus*, *Bosmina longirostris*, Chydorus, Pleuroxus and Cyclops, were among the Entomostraca. *Corixa alternata* was found among the Hemiptera. Most of the Diptera (i. e., fifteen per cent.) were larval Chironomus.

Food of the Adult.

Six adults from rivers, streams and lakes in central and southern Illinois, show the usual change in food, carried farther than in the preceding species. Entomostraca disappear—except a few Chydorus in a single specimen—and fishes become the principal reliance, amounting to forty-seven per cent. of the food. Corixas, larvæ of *Palingenia bilineata*, and some terrestrial Coleoptera—*Anomala binotata*—which made half the food of one specimen, are the remaining items.

The especially piscivorous habit of this species is probably related to the size of its mouth, which is much the largest among the sunfishes proper. A similar relation has already been noticed between the two black bass.

TABLE OF FOOD OF AMBLOPLITES AND CHÆNOBRYTTUS.

	AMBLOPLITES.				CHÆNOBRYTTUS.			
	Under one inch.	One inch to two.	Three to four inches.	Adults.	One inch and under.	One inch to two.	Two to three inches.	Adults.
Number of specimens examined	3	3	2	4	2	4	4	6
I. FISHES	....	....	....	15	....	....	....	47
II. INSECTS	39	99	97	52	....	57	64	53
Undetermined larvæ	....	16	....	01	....	....	....	....
Caterpillars	....	17	....	....	....	....	....	....
1. *Diptera* (larvæ)	05	03	....	06	....	32	04	....
Chironomus	05	03	....	....	....	26	04	....
2. *Coleoptera*	....	....	02	03	....	....	....	10
Terrestrial	....	....	01	....	....	....	....	10
Aquatic	....	....	01	03	....	....	....	....
Dytiscidæ	....	....	01	01	....	....	....	....
Hydrophilidæ	....	....	....	02	....	....	....	....
3. *Hemiptera*	....	63	95	....	....	....	20	18
Corixa	....	63	90	....	....	....	20	18
Hygrotrechus (young)	....	....	05	....	....	....	....	....
4. *Neuroptera* (larvæ)	34	....	....	42	....	25	40	25
Ephemeridæ	....	....	....	21	....	03	12	25
Palingenia	....	....	....	....	....	....	....	25
Baetis	....	....	....	01	....	....	....	....
Agrionidæ	....	....	....	01	....	10	28	....
Libellulidæ	....	....	....	05	....	....	....	....
Phryganeidæ	....	....	....	15	....	....	....	....
III. ARACHNIDA (Hydrachna)	....	....	....	†	....	....	....	....
IV. CRUSTACEA	61	....	03	31	100	43	34	†
Decapoda (Cambarus)	....	....	....	31	....	....	....	....
Amphipoda	....	....	03	....	....	....	....	....
Entomostraca	61	01	....	....	100	43	34	†
Cladocera	58	....	....	....	70	24	34	†
Daphnia	....	....	....	....	....	....	21	....
Bosmina	....	....	....	....	70	....	....	....
Pleuroxus	33	....	....	....	....	†	....	....
Chydorus	....	....	....	....	....	....	†	†
Copepoda	03	01	....	....	30	19	....	....
V. VEGETATION	....	....	....	02	....	....	02	....
Potamogeton	....	....	....	02	....	....	....	....
Algæ	....	....	....	....	....	....	02	....

APOMOTIS CYANELLUS, Raf. BLUE-SPOTTED SUNFISH.

This species, distributed throughout the state, is especially abundant in central Illinois, where it is the common fish of the ponds and smaller streams,—"the sunfish" of the country schoolboy and the picnic party. It is the constant companion of the "bull-head" (Amiurus) and "shiner" (Notemigonus) in the small stagnant ponds of the prairie regions, and of the "chub minnow" (Semotilus) in muddy creeks. It was found abundant with Centrarchus, Aphredoderus and *Amiurus catus*, in the rapidly drying mud-holes,* only a few feet across, left by the retreating overflow of the Mississippi bottoms, in Union county.

Food of the Young.

The smallest of nineteen specimens studied, was one inch in length—taken in July, in a prairie pond near Normal. Ninety-five per cent. of its food was Cyclops and three per cent. Daphnids. The trifling remainder consisted of a Corixa just hatched, and a Chironomus larva.

Nine specimens, ranging from one to two and a fourth inches in length, vary so little in food that it is not worth while to treat them separately. These were taken from various ponds, streams and lakes in central Illinois. Their food was distributed quite generally through the various orders of insects and crustaceans accessible to them, showing the indifferent appetite of this fish and the general effectiveness of its collecting apparatus.

Larvæ of Chironomus, Dytiscidæ, Staphylinidæ, Corixas, Ephemerid larvæ, Decapoda, Isopoda, Cladocera, Cyprids and Copepoda were all found in considerable quantities in the food of these specimens. As usual, the most important insects were Corixas and May-flies,—sixteen per cent. of the former and twenty-nine per cent. of the latter. About eight per cent. of the food was Cladocera (Daphnia, Simocephalus, Pleuroxus, Chydorus).

Food of the Adult.

The eight adults, from northern and southern Illinois, differed from the young in the disappearance of En-

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*All the specimens taken from these holes, so muddy that the water was almost opaque, were of a peculiarly bleached appearance,—many of them almost colorless,—a fact of interest relative to the laws of coloration among fishes.

tomostraca from the food, the larger size of the insects taken, and the appearance of fishes and crawfishes.

Among the insects were a large Hydrophilus unknown to me, but nearly as large as *H. triangularis*, the larva of *Corydalis cornutus*, of Libellula and of some Ephemerid. The fishes composed about thirty-six per cent. of the food. The only recognizable specimens were a small Cyprinoid and a young buffalo-fish (*Ichthyobus bubalus*). Crawfishes and the river shrimp (Palæmonetes) had been eaten by two of the specimens.

LEPIOPOMUS PALLIDUS, Mit. COMMON SUNFISH.

This abundant, hardy and voracious species, is found throughout the state, and may be regarded as the typical sunfish. It is most plentiful in the larger rivers in central Illinois, being replaced in ponds by *Apomotis cyanellus*.

Consistently with its wide range and varied habitat, it is a general feeder for a sunfish,—peculiar only in the fact of its strictly non-predaceous character. Of forty-five specimens examined, only one had eaten a fish, and that one only a single small darter.

Undifferentiated Centrarchidæ.—I introduce here the food of six specimens of this family which were too small for determination. They were too deep for Micropterus, and as they had but three anal spines, could not have been Ambloplites or Pomoxys. They were probably *Lepiopomus pallidus*. All were taken from the Illinois River,—a part of them near La Salle, in July, 1879,—the others from Peoria, in June, 1878.

The smallest (seven-sixteenths of an inch long) had eaten only Daphniidæ. The next in size (one-half inch) contained Cyclops (ninety-eight per cent.) and Chydorus. Nearly the whole of the food of the remaining four was Daphniidæ (ninety-four per cent.), including *Daphnia pulex*.

Food of the Young.

My smallest specimens, five in number, ranging from three-fourths of an inch to one inch, were taken in August, September and October, at Pekin, Peoria and Mackinaw Creek, Woodford county. Neither locality nor date seems to have made any marked difference in their food, the principal elements of which were Entomostraca and Chironomus larvæ—fifty-seven per cent. and thirty-seven per cent. respectively.

A few water-spiders (Hydrachnidæ) and undetermined Amphipoda were the other items. The Entomostraca were all Cyclops (twenty per cent.) and Cladocera (*Simocephalus vetulus* and *americanus*, *Bosmina longirostris* and *Pleuroxus dentatus*).

Nine specimens, between two and three inches long, were caught at the same times and places as the preceding, except that one specimen from Mackinaw Creek was taken in June, and one taken in September was from Clear Lake, Kentucky. The greater size of these specimens was indicated by the appearance of a few Neuroptera larvæ in the food—eight per cent. In other essential respects, the food was like that of the foregoing group. One specimen had eaten largely of water-mites and another of Cyprids (fifty per cent.), and these elements have therefore greater prominence in the averages. Chironomus larvæ and Entomostraca now sum up eighty-one per cent.

In the third group of the young, consisting of seven fishes, between two and three inches long, the Chironomus larvæ remain about as before (thirty per cent.), Corixas appear (twenty-five per cent.) and Neuroptera larvæ rise to fourteen per cent. Entomostraca now fall away to a trifle, and larger percentages of Amphipoda appear. Single fishes had eaten the larvæ of a Gyrinid beetle, portions of the Polyzoan *Pectinatella magnifica*,* Leidy, and an earthworm,—the latter probably nibbled from some fisherman's hook.

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*This animal forms the large, translucent masses found in midsummer in the slow water along the margins of the Illinois River and elsewhere throughout the state, usually collected about a stick or a stem of a waterweed. They vary from the size of a walnut to that of half a bushel. The fragments were easily recognized by the peculiar form and armature of the winter eggs (statoblasts), which are discoidal and bordered with a row of slender double hooks, shaped something like an anchor.

These specimens were all from the Illinois River, in June, July, October and November.

Food of the Adult.

The twenty-four adults examined were from various parts of the state north of the center; and, as the food has been found to differ so widely according to the local situation, I have treated them in three groups,—the first including those taken in the clear, inland, northern lakes; the second those from Calumet River, at South Chicago, and the shallow, muddy lakes of that vicinity, and the third those from the Illinois River from Ottawa to Peoria.

The specimens from the northern lakes were taken in May and June. Sixty-two per cent. of the food consisted of Neuroptera,—eight per cent. being a black caddis-fly (*Sialis infumata*) and the remainder the larvæ of large dragon-flies (Libellulidæ), Agrions (eleven per cent.) and Baëtis (two per cent.). *Allorchestes dentata* was the next most important element (twenty-seven per cent.). A number of terrestrial insects besides Sialis appeared in the food. These included a Harpalid beetle, an *Aphodius fimetarius*, and some grasshoppers (Tettigidæ, etc.).

The second group of four, from Calumet River, and from Lake George, Indiana, was peculiar in the number of tetradecapod Crustacea and case-worms taken, and especially in the amount of vegetation eaten.

The Crustacea were Allorchestes (thirty-two per cent.) and Asellus (twenty per cent.). The vegetation was present in such quantities as to make it evident that it had been taken as food. It amounted to about a fourth of the contents of these stomachs. The stomach of one fish was packed with a piece of the stem of a plant (apparently a Scirpus) a third of an inch in diameter and six inches long. Three others contained smaller amounts of confervoid Algæ.

The fifteen specimens remaining were taken from the Illinois in May, July, August, October and November. Their food was especially noticeable for the presence of mollusks (sixteen per cent.), for the number and variety of land insects (fifteen per cent.), and for the large amount of vegetation it contained (thirty-one per cent.). A single small fish—the only one taken by these forty-five specimens—was also noticed.

The mollusks included Planorbis, Physa, Amnicola and Vivipara. Among the insects, were ants, caterpillars, flies, *Anisodactylus discoideus* and other Harpalids, *Aphodius inquinatus*, wire-worms, minute curculios, *Cryptocephalus* 4-*maculatus*, *Diabrotica* 12-*guttata*, Colorado potato beetles, flea-beetles, plant-bugs (Pentatomidæ), crickets (Nemobius), locusts, katydids (*Phaneroptera curvicauda*), grasshoppers and case-flies.

The vegetable food, as far as determined, consisted of Ceratophyllum, *Nais flexilis* and confervoid Algæ. Fragments of Polyzoa were noticed. *Coptotomus interrogatus*, Gyrinid larvæ,* *Tropisternus limbatus* and other Hydrophilidæ, larval and adult, a large Nepa, larvæ of *Palingenia bilineata* and other May-flies, of Agrions and dragon-flies were among the aquatic insects taken.

The Crustacea were limited to small crawfishes (two per cent.), a trace of Allorchestes, and a few Aselli (four per cent.).

On comparing specimens from northern Illinois with those taken from the Illinois River in the same month, I find that there are no common seasonal food characters, and that the differences of food are therefore due to difference of locality and not to difference of time represented by the groups. Concerning the entire number of adults, we can therefore say that their food ranges through the whole list of the smaller mollusks, terrestrial and aquatic insects, and smaller crustaceans (above Entomostraca) accessible in their localities, and that they feed largely on aquatic vegetation. A striking negative feature is the almost total absence of fishes in the food,—a fact which corresponds with the relatively small size of the mouth.

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*Several of these little-known larvæ were found in the stomachs of this species,—some of them in suitable condition for description.

TABLE OF FOOD OF APOMOTIS AND LEPIOPOMUS.

	Apomotis.			Lepiopomus.						
	One inch long.	One to four inches.	Adults.	One inch and under.	One inch to two.	Two to three inches.	Northern lakes.	Calumet river and lakes.	Illinois river.	Total adults.
Number of specimens..	1	10	8	5	9	7	5	4	15	24
I. FISHES...........	....	....	36	....	....	....	....	....	10	01
Undetermined.........	....	....	10	....	....	....	...	....	....	....
Etheostomatidæ.......	....	. ..	....	....	....	...	....	....	01	....
Cyprinidæ	....	...	13	....	...	....	....	....	....	....
Ichthyobus............	....	....	13	....	....	....	...	....	....	....
II. MOLLUSKS.......	....	....	....	....	....	....	....	....	16	10
1. *Gasteropoda*........	....	..	....	....	....	....	....	....	16	10
Undetermined.......	....	....	....	....	....	....	...	....	04	....
Planorbis	....	...	....	....	....	....	....	....	†	....
Physa..............	....	....	...	....	....	....	....	....	05	....
Vivipara.......	....	....	....	....	....	....	....	†	07	....
Amnicola	....	....	....	....	....	....	...	....	†	†
2. *Acephala*....	....	....	....	....	....	....	....	...	†	....
III. INSECTA........	02	79	42	37	34	72	70	23	43	45
Undetermined.........	....	12	01	....	....	02	....	....	....	....
Terrestrial	....	07	....	....	....	....	05	01	15	12
Aquatic...............	02	60	41	37	34	70	65	22	28	33
1. *Diptera* (Chironomus)	01	09	....	37	26	30	....	†	01	01
2. *Coleoptera*..........	....	02	05	....	....	01	01	01	09	06
Undetermined.......	....	....	....	....	....	....	....	†	04	....
Dytiscidæ...........	....	02	....	....	....	....	....	....	02	....
Undetermined.....	....	02	....	....	...	....	....	....	....	....
Larvæ	....	....	....	....	....	....	....	....	01	....
Coptotomus	....	....	....	....	....	....	....	....	01	....
Gyrinidæ (larvæ)......	....	....	....	....	....	01	....	01	01	...
Hydrophilidæ	....	....	....	....	....	....	01	....	02	....
Undetermined.......	....	....	05	....	....	....	....	....	01	....
Tropisternus	....	....	....	....	....	....	....	....	01	....
3. *Hemiptera*..........	01	16	03	†	....	25	02	01	04	02
Undetermined.......	....	....	....	†	....	....	....	....	....	....
Corixa	01	16	03	....	....	25	01	....	04	....
Nepa	....	....	....	....	....	....	01	....	....	....
Ranatra.............	....	....	....	....	....	....	....	01	....	....
4. *Neuroptera*.........	....	33	33	....	08	14	62	20	14	24
Larvæ (undetermined)..	....	....	....	....	01	....	....	....	....	....
Ephemeridæ (larvæ)....	....	29	27	....	07	....	02	....	05	03
Baetis...............	....	....	....	...	....	....	02	....	....	....
Palingenia	....	....	01	....	....	....	....	....	04	02
Agrionidæ (larvæ).....	....	....	06	....	....	14	11	....	†	10
Libellulidæ (larvæ)....	....	04	02	....	....	....	41	....	02	02

TABLE OF FOOD OF APOMOTIS AND LEPIOPOMUS—Continued.

	APOMOTIS.			LEPIOPOMUS.						
	One inch long.	One to four inches.	Adults.	One inch and under.	One inch to two.	Two to three inches.	Northern lakes.	Calumet river and lakes.	Illinois river.	Total adults.
Number of specimens..	1	10	8	5	9	7	5	4	15	24
Sialidæ	....	....	04	....	....	....	08	....	07	06
Sialis	....	....	....	....	....	....	08	....	07	06
Corydalis (larvæ)	....	....	04	....	....	....	....	....	....	....
Phryganeidæ	....	....	....	....	....	....	....	20	....	03
IV. ARACHNIDA	....	....	....	04	11	01	01	....	....	....
Spiders	....	....	....	....	....	....	01	†	....	....
Hydrachnidæ	....	....	....	04	11	01	....	....	†	....
V. CRUSTACEA	98	21	20	59	55	06	27	52	06	18
Decapoda	....	01	20	....	....	....	....	....	02	01
Undetermined	....	01	....	....	....	....	....	....	....	....
Cambarus	....	....	08	....	....	....	....	....	02	....
Palæmonetes	....	....	12	....	....	....	....	....	....	....
Amphipoda	....	....	....	02	....	05	27	32	....	11
Undetermined	....	....	....	02	....	....	....	....	....	....
Allorchestes	....	....	....	....	....	05	27	32	†	....
Isopoda (Asellus)	....	04	....	....	....	....	....	20	04	06
Entomostraca	98	16	....	57	55	01	....	†	....	....
Cladocera	....	08	....	37	14	....	....	†	....	....
Daphniidæ	03	07	....	33	12	....	....	....	....	....
Lynceidæ	....	01	....	04	02	01	....	†	....	....
Ostracoda	....	03	....	....	06	....	....	†	†	....
Copepoda	95	05	....	20	35	†	....	....	....	....
VI. VERMES	....	....	....	....	....	20	....	....	03	02
Undetermined	....	....	....	....	....	†	....	....	....	....
Polyzoa	....	....	....	....	....	11	....	....	03	02
Lumbricus	....	....	....	....	....	09	....	....	....	....
VII. VEGETATION	....	....	02	....	....	01	02	25	31	24
Phænogamous	....	....	02	....	....	01	02	21	19	16
Algæ	....	....	....	....	....	....	....	04	12	08

XENOTIS MEGALOTIS, Raf. LONG-EARED SUNFISH.

This little species is not at all common in the state, but has been taken by us from the middle course of Fox R., from tributaries of the Illinois R., and from ponds in Union county and southern Illinois.

Unfortunately, the three specimens examined had not lately taken food, and only a very imperfect notion of their usual aliment can be given. Corixa, Ephemerid larvæ, Chironomus larvæ, the tube of a case-worm, a few fish-scales and an indeterminable aquatic beetle were the only objects found.

XENOTIS PELTASTES, Cope.*

This beautiful little fish, hitherto taken in this state only in very small number from Fox R., was found quite abundant in the "slip" at South Chicago, in June, 1880. The three opened had eaten more larvæ of Chironomus than anything else (sixty per cent.). Next came sixteen per cent. of mollusks, then Allorchestes and Asellus, Corixa, Gyrinid larvæ and a few terrestrial larvæ (Chrysomelidæ). The large percentage of Chironomus was probably owing to the situation,—a foul and muddy little bay, serving as a harbor for fishing-boats.

EUPOMOTIS AUREUS, Walb. PUMPKIN-SEED. BREAM.

This species swarms in the lakes and ponds of northeastern Illinois, but is much less abundant in the Illinois R., and in the southern part of the state is almost unknown. The cause of this limitation of its range is apparently climatic, as there is certainly nothing in its food, nor, apparently, in any of its habits, to exclude it from our southern waters. Indeed, I do not see that its place is taken by any other fish to the southward. No other, unless *Eupomotis pallidus*, resembles it in food, and this is too infrequent to replace it. My knowledge of its food is based upon the study of twenty-five specimens, ranging from one and one-half inches upward, taken from the Illinois, Fox and Calumet rivers, and from Long, Crystal and Nipisink lakes and Lake George, in central and northern Illinois and Indiana. The months of May, June, July, August and October are represented by these specimens.

Food of the Young.

The nine smaller specimens, from one and one-half to two inches long, show at once two prominent peculiarities of the food. The larvæ of Chironomus compose fifty-one

*It is considered doubtful, by Dr. Jordan, if this species and the preceding are distinct.

per cent. of the food, and Entomostraca of the order Ostracoda (Cyprids), twenty-six. As both these are found most abundantly in muddy bottoms, it is evident that the fish is, at least at first, a bottom feeder. Traces of mollusks appear thus early, as well as a few Ephemerid larvæ (five per cent.). The remainder of the food was insects' eggs and Daphnids,—chiefly *Simocephalus americanus*—(twelve per cent.). Chydorus was found in five specimens, but in too small quantity to figure in the averages.

Five specimens were studied between two and three inches long. In these the same food characters continue, modified somewhat by the introduction of larger objects. The Chironomus larvæ stand at forty-four per cent., and the Cyprids at eighteen per cent. Fourteen per cent. of Allorchestes and eleven per cent. of Neuroptera larvæ are the only important elements remaining. Two per cent. of young Unios were noticed. Nearly half of the food of two larger specimens, between two and three inches long, consisted of mollusks,—chiefly Physa. A few Chironomi and about equal quantities of Ephemerid larvæ and Allorchestes were all the remaining food. Entomostraca therefore disappear at this point.

Food of the Adult.

Forty-six per cent. of the food of the nine adults consisted of Mollusca, including Planorbis, Amnicola and *Valvata tricarinata*, and six per cent. of undetermined bivalves.

The insect food was twenty per cent. of the whole, Crustacea twenty-two per cent., and vegetation twelve per cent. Half of the last was Chara, and the remainder chiefly Myriophyllum and Algæ. Thc Crustacea were all Allorchestes and Asellus. The insects included a trace of Chironomus larvæ and a few water-beetles (Hydrophilidæ), and the usual Neuroptera larvæ, among which case-flies of the genus Leptocerus were noticed.

Not a trace of fishes was found in the stomachs of these specimens; and this fact, together with the large percentage of molluscan food, constituted the leading alimentary peculiarities of the species.

The first of these is doubtless related to the small mouth,

—the second to the stout, blunt pharyngeal teeth—a character used in defining the genus. In all the preceding species the pharyngeals are set with more slender, pointed teeth.

EUPOMOTIS PALLIDUS Ag. PALE SUNFISH.

Having but few specimens of this rather uncommon species, I have examined the food of but one,—enough to indicate that it probably agrees closely with the preceding species.

This fish, taken in Clear Lake, Ky., had eaten largely of small Mollusca,—young Unionidæ, Planorbis, Amnicola, etc. These amounted to seventy-five per cent. of the food. The remaining elements were Chironomus larvæ, several small water-beetles, (*Hydroporus hybridus*, *Cnemidotus 12-punctatus*, and *Haliplus*, sp.), an unknown aquatic pupa and a little pond-weed.

CENTRARCHUS IRIDEUS, Lac.

This little species is found in considerable numbers in ponds and streams in the southern hill-country of Illinois. My specimens, all taken in July, are from ponds and streams in the Mississippi bottoms in Union and Jackson counties, and from Cache R. and its tributaries in Johnson county.

Five of the young, from three-fourths of an inch to an inch in length, had eaten seventy-one per cent. of Entomostraca and twenty-one per cent. of larvæ of Chironomus and, for the rest, about equal quantities of Ephemerid larvæ and young Allorchestes, with a trace of water mites (Hydrachnidæ).

Thirty-eight per cent. of the food was Cyclops; Cyprids amounted to twenty-one per cent.; and twelve per cent. of Simocephalus completed the ratio of Entomostraca. The smallest specimen, three-fourths of an inch long, had eaten sixty per cent. Simocephalus and forty per cent. Cyclops.

About a fifth of the food of one specimen, an inch and an eighth in length, consisted of minute young Corixas, the remainder being about equally Cyclops and Cyprids.

TABLE OF FOOD OF EUPOMOTIS AND CENTRARCHUS.

	EUPOMOTIS.				CENTRARCHUS.		
	One inch to two.	Two to three inches.	Three to four inches.	Adults.........	One inch and under.	One inch to two.	Adults.
Number of specimens examined......	9	5	2	9	5	1	2
I. MOLLUSCA..................	01	04	45	46	....	....	....
Undetermined..................	....	....	....	07	....	....	....
Gasteropoda..................	01	02	45	33	....	....	....
Amnicola..................	....	....	....	04	....	....	....
Vivipara..................	....	....	....	11	....	....	....
Planorbis..................	....	....	....	01	....	....	....
Physa..................	....	....	40	....	....	....	....
Acephala..................	....	02	....	06	....	....	....
II. INSECTA..................	60	61	30	20	24	20	91
Undetermined..................	03	03	....	....	...	....	07
1. *Diptera* (larvæ)..................	52	45	05	01	21	....	06
Chironomus..................	51	44	05	01	21	....	06
2. *Coleoptera*..................	....	02	....	02	....	....	....
Hydrophilidæ..................	....	02	....	02	....	....	....
3. *Hemiptera*..................	....	....	....	....	....	20	23
Corixa..................	....	....	....	....	....	20	23
4. *Neuroptera* (larvæ)..................	05	11	25	17	03	....	55
Ephemeridæ..................	05	05	25	03	03	....	55
Palingenia..................	....	....	....	03	....	....	....
Agrionidæ..................	....	06	....	....	....	....	....
Libellulidæ..................	....	....	....	08	....	....	....
Phryganeidæ..................	....	....	....	02	....	....	....
III. ARACHNIDA..................	....	....	....	....	01	....	....
Hydrachnidæ..................	....	....	....	....	01	....	....
IV. CRUSTACEA..................	39	35	25	22	75	80	....
Amphipoda (Allorchestes)..................	....	14	25	13	04	....	....
Isopoda (Asellus)..................	....	....	....	09	....	....	....
Entomostraca..................	39	21	....	....	71	80	....
Cladocera..................	13	03	....	....	12	....	....
Simocephalus..................	12	01	....	....	12	....	....
Ostracoda..................	26	18	....	....	21	35	....
Copepoda..................	....	....	....	....	38	45	09
V. VEGETATION..................	....	†	....	12	....	....	....
Myriophyllum..................	....	....	....	04	....	....	....
Chara..................	....	....	....	06	....	....	....
Algæ..................	....	†	....	02	....	....	....

Only two specimens were examined which could be classed as adults,—one three and a fourth inches long, the other smaller. These indicate that the food of full-grown individuals differs from that of the young chiefly in the addition of considerable quantities of terrestrial and aquatic insects.

The gill-rakers of this species are numerous, long and slender,—a fact reflected in the food. Fifteen per cent. of the contents of the stomach of the largest specimen consisted of Cyclops and five per cent. of Chironomus larvæ. Consistently with the small mouth and pointed pharyngeal teeth, no traces of fishes or mollusks were found in the food.

POMOXYS NIGROMACULATUS, Lac. BLACK CROPPIE. LAKE CROPPIE. SILVER BASS. BUTTER BASS.

POMOXYS ANNULARIS, Raf. WHITE CROPPIE. TIMBER CROPPIE. SILVER BASS.

These two species, often not distinguished even by experienced fishermen, agree so closely in food that I have not thought it worth while to treat them separately. In the Illinois and Mississippi rivers they are much the most valuable and important of the family, excepting the black bass. They are nowhere else so abundant in the state, although occurring in the larger rivers generally and in the Great Lakes. The first species is commonest to the north, and the second southward, so far as my observation goes. In the Illinois, they are about equally abundant. These fishes are everywhere great favorites, and rank among the most important and promising of our smaller species. They are rarely found in creeks or small ponds, but seem to require deeper water for their maintenance.

The gill-rakers of this species are numerous, long, and finely toothed, constituting the most efficient straining apparatus to be found among the sunfishes. The pharyngeal teeth are sharp, and the mouth is rather wide and considerably enlarged by the lengthening of the lower jaw.

Consistently with the hypothesis concerning the meaning of the gill-rakers which I had already formed from a study of the preceding species, before I came to this, I found that the young continued to feed almost exclusively upon Entomostraca much longer than the other sunfishes. Six specimens between three and four inches long, had eaten little else than Entomostraca and the larvæ of minute Diptera (Chironomus and Corethra). Even full-grown specimens were found eating Cladocera more freely than any other food. As might be inferred from the pharyngeals, not a trace of molluscan food was found in the forty-two specimens examined, while fishes formed nine per cent. of the food of the twenty-seven adults. Most of these were eaten late in the season, when Entomostraca and insect larvæ became less abundant.

Food of the Young.

The smallest specimen, three-fourths of an inch long, had eaten about equal quantities of Cyclops and Simocephalus, with only a few Pleuroxus beside. Three, an inch long and under, had confined their food entirely to Entomostraca and Chironomus larvæ,—the latter forming about a fourth of the whole. A third of the Entomostraca were Cyclops, the remainder chiefly Simocephalus.

Six specimens between one and three inches long, differed especially in the introduction of about eighteen per cent. of Corixas and three per cent. of small Ephemerid larvæ. Chironomus larvæ were reduced to seven per cent. The Entomostraca were about equally divided between Cyclops and Cladocera. One specimen taken in July, 1879, from the canal near Ottawa, had taken a large number of Daphnella.

Six specimens between three and four inches long were examined. Eighty-three per cent. of their food was Entomostraca, about three-fourths of this amount being Cyclops, and the remainder nearly all Simocephalus. Twelve per cent. of larvæ of Chironomus and Corethra, three per cent. Corixas and two per cent. larvæ of small Ephemerids were the insect elements. Chydorus, Pleuroxus and Cypris were present in small numbers.

These fifteen young, agreeing so closely in food, irrespective of size, were nevertheless from a variety of situations and dates. All were from the Illinois River, its lakes and tributaries, from Ottawa to Pekin, but ranged in time from June to October of three different years.

Six were *P. nigromaculatus*, seven were *P. annularis*, and two were not identified specifically.

Food of the Adults.

An examination of the notes on the twenty-seven adults shows material differences of food at different parts of the year. As all but one were taken from the Illinois River, I have not the means of noting the correspondence of food with locality.

Five specimens taken at Peoria, in March, were found feeding most freely upon Cladocera, which composed fifty-five per cent. of their food. These were chiefly of the two species *Simocephalus vetulus* and *S. americanus*. These little Entomostraca were taken at that time in such quantity as visibly to distend the stomach when seen from the outside, and the immense number of their eggs gave a reddish color to the contents of the alimentary canal. The larvæ of Neuroptera, both "darning-needles" and May-flies (Palingenia), were also eaten in considerable numbers (thirty-nine per cent.). A small Hybopsis, a little darter (*Boleosoma maculata*) and an unrecognizable fish were found in these stomachs, making about six per cent. of the food. Only trivial numbers of Entomostraca appear after this time.

Nine specimens, taken in April, likewise at Peoria, were feeding chiefly upon Neuroptera larvæ (eighty-six per cent.), especially upon that almost invaluable element of fish food, the larvæ of *Palingenia bilineata* (sixty-six per cent.). A few larvæ of Gyrinidæ and Dytiscidæ were noted (three per cent.), and a few Corixas also. A *Gammarus fasciatus* and a little Ceratophyllum, etc., were noticed; and also the flower of an elm and the feather of a bird.

A single specimen from Pistakee Lake, in McHenry county, taken in May, gave evidence of a similar reliance upon Neuropterous larvæ (eighty-five per cent.). Here, however, in the absence of Palingenia, Agrions and the larger dragon-flies were resorted to. A little vegetation had been taken with these (*Ceratophyllum demersum* and *Lemna trisulca* ten per cent.), probably by accident, as this lake was full of aquatic plants, and it would hardly have been possible for a fish to catch living food from the water without getting more or less vegetation at the same time. A single Hymenopter,—the only land insect found eaten by this species,—was taken from this stomach. A specimen taken in June at Peoria had eaten about equally of minute unrecognized fish-fry and Palingenia larvæ. One caught at Ottawa, in July, had eaten only insects,—Corixa twenty-five per cent., Palingenia larvæ seventy-five per cent.

TABLE OF FOOD OF POMOXYS.

	One inch and under.	One inch to three.	Three to four inches.	March, Peoria.	April, Peoria.	May, Pistakee L.	June, Peoria.	July, Ottawa.	October, Peoria.	November, Henry.	Total adults.
No. of specimens.....	3	6	6	5	9	1	1	1	5	5	27
I. FISHES	..	....	....	06	....	....	50	....	39	28	15
Acanthopteri..........	..	....	....	....	....	..	....	....	10	08	03
Boleosoma..........	..	....	....	01	....	....	...	....	....	....	....
Cycloid..............	..	....	....	04	....	....	....	....	11	....	....
Cyprinidæ	..	....	....	04	....	....	....	....	11	....	03
Hybopsis.........	..	......	.....	04	...	..	....	....	....	....	01
II. INSECTS.........	28	28	17	39	90	90	50	100	61	72	73
1. *Hymenoptera*......	..	....	....	....	....	05	....	....	...	......	......
2. *Diptera* (larvæ)....	28	07	12	....	....	....	....	....	01	02	01
Corethra............	...	†	03	....	....	....	....	....	01	......	......
Chironomus.........	28	07	09	....	†	†	....	....	....	02	......
3. *Coleoptera* (larvæ).	..	....	....	....	03	†	....	....	....	03	01
Gyrinidæ..........	..	....	....	....	02	....	....	....	....	03	....
Dytiscidæ	..	....	....	....	01	....	....	....	....	....	....
4. *Hemiptera*........	..	18	03	....	01	....	....	25	....	....	01
Corixa.....	..	18	03	....	01	†	....	25	....	....	01
5. *Neuroptera* (larvæ)	..	03	02	39	86	85	50	75	60	67	68
Ephemeridæ.......	..	03	02	15	72	....	....	....	44	....	54
Palingenia.......	..	....	....	15	66	....	50	75	44	67	52
Agrionidæ.........	..	....	....	24	14	55	....	....	....	....	12
Libellulidæ........	..	....	....	....	....	30	....	....	....	....	01
Sialidæ (Corydalis).	..	....	....	....	....	....	....	....	16	....	01
III. CRUSTACEA ...	72	72	83	57	10	....	....	....	....	....	12
Gammarus...	..	....	....	....	†	....	....	....	....	....	....
Entomostraca........	72	72	83	55	10	....	....	....	....	....	12
Cladocera	49	33	17	55	10	....	....	....	....	....	12
Daphniidæ	46	18	17	55	†	....	....	....	....	....	12
Lynceidæ	03	01	†	....	....	....	....	....	....	....	....
Sididæ	..	14	....	....	....	....	....	....	....	....	....
Ostracoda	..	....	01	†	†	....	....	....	....	....	....
Copepoda	23	39	65	....	†	....	†	....	....	....	....
IV. VEGETATION ..	..	....	....	†	†	10	†	†	....	....	....

Five croppies from Peoria, in October, 1878, and five from Henry, thirty miles above, in November, 1877, indicate that the autumnal food of the species is again different. These had eaten, respectively, thirty-nine per cent. and twenty-eight per cent. of small fishes,—partly Cyprinidæ and partly undetermined Acanthopteri. The remainder of their food was composed chiefly of Palingenia larvæ. One October specimen had eaten two larvæ of the large "helgramite," *Corydalis cornutus*. Although these fishes were taken directly from the seine, and opened upon the spot, the food in their stomachs did not average more than a fourth of the quantity in those taken in early spring. The weather during both these months was uncomfortably cold, with falling snow, and the food of these specimens probably gives a correct hint of the winter food of the species.

Fourteen of the above were *Pomoxys nigromaculatus* and twelve *P. annularis*,—one not having been determined.

Summary of the Family.

For the purpose of a comparative recapitulation of the above data respecting the food of the sunfishes, I have prepared three condensed tables, showing, upon the same page, the food of the different genera in parallel columns. The first table exhibits the food of the youngest specimens, the second, of those of intermediate size, and the third, of those which may properly be regarded as mature.

By an inspection of the first table, it will be seen that the thirty specimens, one inch long and under, representing eight genera, which appear thereon, have eaten little else than Entomostraca and larvæ of Chironomus,—these two elements amounting to ninety-three per cent. of the food. The only exception to this rule (that of the rock bass) is apparent rather than real. The large percentage of Neuropterous larvæ appearing under the name of that species is a technical ratio, inserted only for the sake of consistency, being based upon the fact that one of the specimens examined contained no food except a few traces of some indeterminable minute larva of that order. The minor differences in the food of the generic groups are doubtless due to differences of locality, and the like. That Ostracoda, for example, were found only in the stomachs of Centrarchus, is accounted for by the fact that the youngest specimens of this genus were taken from small mud-holes, favorable to the occurrence of Entomostraca of that order. The uniformity of food at this time implies that the selective apparatus of these fishes, whatever its construction, has not yet grown beyond the size of these minute animal forms.

From the second table of one hundred and six specimens we learn that with a general change of food from Entomostraca and Chironomus to larger Crustacea and insects, there appear certain differences,—notably the continuance of Entomostraca as the most important element in Pomoxys, and the occurrence of mollusks in Eupomotis and of fishes in Micropterus. It is important to recall, at this point, that Pomoxys has the largest, finest and most numerous gill-rakers of the group,—the best *straining* apparatus, in short, —that Eupomotis has stout, blunt pharyngeal teeth, and that the black bass have relatively the widest mouths of all. It is also to be noted that the large-mouthed bass commenced to take fish when an inch and a quarter long, and the small-mouthed species not until it reached a length of two and a half inches.

It will also be observed that Entomostraca are least abundant in the food of the small-mouthed black bass and the rock bass,—species found usually in swift and shallow water, when of this size. The importance of water-bugs (Corixa) to the first three species of this table is evident.

From the table of adult food we find that these commencing peculiarities of the preceding table become here more prominent. All the Entomostraca of this table, except insignificant traces, now appear in the food of Pomoxys; the molluscan food of Eupomotis is nearly five times that of any other genus; and the ratios of fish food, running from eighty-six per cent. down to nothing, when arranged in a series, are seen to correspond, with curious exactness, to a series of the species themselves arranged according to the relative sizes of their mouths.

I was disappointed in being unable to find any food characteristics corresponding to such minor differences in the length of the gill-rakers of the anterior arch as appear in Lepiopomus, Apomotis, etc., on the one hand, and Xenotis and Eupomotis on the other. If such peculiarities exist, they can probably be determined only by taking at one time and place a number of specimens of unlike character in this particular.

While I believe that the generalizations made above will hold good, at least for fishes of similar form and internal structure among the Acanthopteri, I do not wish to be understood as extending them at present beyound this order. Doubtless, while the characters mentioned must assist greatly in determining the food of a species *a priori*, they are not by any means sufficient for this purpose when taken by themselves. The discussion of other features, external and internal, bearing upon this subject, must be postponed to a later period of the investigation.

TABLE OF FOOD OF YOUNG CENTRARCHIDÆ. (*One inch and under.*)

	Micropterus pallidus.	Micropterus salmoides.	Ambloplites.	Chænobryttus.	Apomotis.	Lepiopomus.	Eupomotis.	Centrarchus.	Pomoxys.	Undetermined.	Total.
Number of specimens	5	..	3	2	1	5	..	5	3	6	30
I. INSECTS	....	..	39	....	02	37	..	24	28	....	17
1. *Diptera* (larvæ)	....	..	05	....	01	37	..	21	28	....	13
Chironomus	....	..	c5	....	01	37	..	21	28	....	13
2. *Hemiptera*	....	..	..	....	01	..	..	..	..	....	..
Corixa (young)	....	..	..	....	01	..	..	..	..	....	..
3. *Neuroptera* (larvæ)	...	..	34	....	..	..	..	03	..	....	04
II. ARACHNIDA (Hydrachna)	....	..	..	....	..	04	..	01	..	....	01
III. CRUSTACEA	100	..	61	100	98	59	..	75	72	100	82
Tetradecapoda	07	..	..	....	..	02	..	04	..	....	02
Entomostraca	93	..	61	100	98	57	..	71	72	100	80
Cladocera	87	..	58	70	03	37	..	12	49	88	53
Ostracoda	....	..	..	....	..	..	..	21	..	†	04
Copepoda	06	..	03	30	95	20	..	38	23	22	23

TABLE OF FOOD OF YOUNG CENTRARCHIDÆ. (*One to four inches.*)

	Micropterus pallidus.	Micropterus salmoides	Ambloplites.	Chænobryttus.	Apomotis.	Lepiopomus.	Eupomotis.	Centrarchus.	Pomoxys.
Number of specimens	12	24	5	8	10	16	16	3	12
I. FISHES	15	06	....	....	....	....	....	....	....
II. MOLLUSCA	....	....	....	....	....	....	08	....	....
III. INSECTA	72	67	98	61	78	51	56	67	22
1. *Diptera* (larvæ)	01	03	02	18	09	28	44	04	09
Chironomus	01	01	02	15	07	28	43	04	08
2. *Coleoptera*	....	02	01	....	09	†	01	....	....
Terrestrial	....	....	....	....	07	....	....	....	....
Aquatic	....	02	01	....	02	†	01	....	....
3. *Hemiptera* (aquatic)	50	50	78	10	16	11	....	23	11
Corixa	49	50	76	10	16	11	....	23	11
4. *Neuroptera*	14	12	....	33	33	11	10	37	02
Ephemeridæ	14	08	....	08	29	05	08	37	02
Odonata	....	04	....	19	04	06	02	....	....
IV. ARACHNIDA	....	....	....	....	....	07	....	....	....
V. CRUSTACEA	13	26	02	38	22	32	36	33	78
Decapoda	....	....	....	....	01	....	....	....	....
Tetradecapoda	....	23	01	....	04	....	08	....	....
Entomostraca	13	03	01	38	17	32	28	33	78
Cladocera	07	03	....	29	09	08	08	....	25
Ostracoda	....	....	....	....	03	03	20	12	01
Copepoda	06	†	01	09	05	20	....	21	52
VI. POLYZOA	....	....	....	....	....	05	....	....	....
VII. LUMBRICUS	....	....	....	....	....	04	....	....	....
VIII. VEGETATION	....	01	....	01	....	01	....	....	....

TABLE OF FOOD OF ADULT CENTRARCHIDÆ.

	Micropterus pallidus.	Micropterus salmoides.	Ambloplites.	Chænobryttus.	Apomotis.	Lepiopomus.	Xenotis.	Eupomotis.	Centrarchus.	Pomoxys.
Number of specimens	14	3	4	6	8	24	6	9	2	27
I. FISHES	86	38	15	46	36	01	07	....	....	15
Acanthopteri	15	....	....	....	....	01	....	....	....	03
Dorysoma	58	....	....	....	....	....	....	....	....	....
Cyprinidæ	06	....	....	....	12	....	....	....	....	03
Siluridæ	07	....	....	....	....	....	....	....	....	....
II. MOLLUSCA	....	....	....	....	....	10	08	46	....	....
Gasteropoda	....	....	....	....	....	10	04	33	....	....
Acephala	....	....	....	....	....	†	04	06	....	....

TABLE OF FOOD OF ADULT CENTRARCHIDÆ—Continued.

	Micropterus pallidus.	Micropterus salmoides.	Ambloplites.	Chænobryttus.	Apomotis.	Lepiopomus.	Xenotis.	Eupomotis.	Centrarchus.	Pomoxys.
Number of specimens...	14	3	4	6	8	24	6	9	2	27
III. INSECTA.........	†	....	52	54	42	45	82	20	91	73
1. *Hymenoptera* (ants)..	....	....	....	....	....	....	....	....	07	....
2. *Diptera* (larvæ)......	....	....	06	....	....	01	37	01	06	01
Chironomus..........	....	....	....	...	....	....	37	01	06	....
3. *Coleoptera*...........	....	....	03	10	05	13	06	02	....	01
Terrestrial...........	....	....	....	10	....	06	04	....	....	....
Aquatic..............	....	....	03	....	05	....	....	02	....	01
4. *Hemiptera* (Corixa)..	†	....	....	18	03	02	17	....	23	01
5. *Orthoptera*..........	....	....	....	....	....	02	....	....	....	....
6. *Neuroptera*..........	†	....	42	25	33	24	16	17	55	68
Ephemeridæ.........	....	....	21	25	27	03	....	04	55	52
Palingenia.........	....	....	....	25	01	02	....	03	....	52
Odonata.............	....	....	06	....	02	12	....	08	....	13
Sialidæ..............	....	....	....	....	04	06	....	....	....	01
Phryganeidæ.........	....	....	15	....	....	03	08	01	....	....
IV. ARACHNIDA	....	....	†	....	....	....	....	...	....	....
V. CRUSTACEA	07	62	31	†	20	18	03	22	09	12
Decapoda..............	07	62	31	....	20	01	....	....	....	....
Tetradecapoda.........	....	....	....	....	....	17	03	22	....	....
Entomostraca..........	...	....	....	†	....	†	....	....	09	12
Cladocera............	....	....	....	†	....	†	....	....	....	12
Ostracoda............	....	....	....	....	....	†	....	....	....	†
Copepoda............	....	....	....	....	....	....	....	....	09	†
VI. POLYZOA.........	....	....	....	....	. ..	02	....	....	....	....
VII. VEGETATION ...	†	....	02	....	02	24	....	12	....	†
Miscellaneous........	07	....	....	....	...	....	....	....	...	....

HAPLOIDONOTUS GRUNNIENS, Raf. SHEEPSHEAD. GRUNTING PERCH.

This species is abundant in Lake Michigan and the larger rivers, occurring in the smaller streams rarely, at periods of exceptionally high water. It is sometimes eaten, but is regarded usually as unfit for food.

But six of the twenty-five specimens studied were young, and the smallest of these, from the Ohio R., in September, was an inch and an eighth in length. Seventy-five per cent. of its food was larvæ of Chironomus and twenty-five per cent. larvæ of *Palingenia bilineata*. Besides the usual indications that the food of the very young is made up of minute animals, we see here evidence that this species seeks its food from the first upon the bottom. In a specimen two inches long, the Chironomus larvæ fell to fifteen per cent, while the Palingenia larvæ rose to eighty per cent., and other Ephemerids and Cyclops made up the remainder of the food.

Four specimens, also from the Ohio, at Cairo, from two to four inches long, were found to have recently fed upon Ephemerid larvæ and larvæ of aquatic beetles, Gyrinidæ and Hydrophilidæ, in about equal quantities. Only five per cent. of their food was Chironomus.

Sixteen individuals of medium size were taken from the Illinois and Ohio rivers, in April, June, September and October of four different years. There was nothing in the contents of these stomachs to indicate any difference in food resulting from these differences of date and situation. The food, on the contrary, was remarkably simple and uniform, consisting chiefly of the larvæ of Neuroptera (eighty-four per cent.), of which *Palingenia bilineata* formed altogether the most important part (seventy-six per cent.),—the remaining eight per cent. being dragon-flies. A single small sucker (Catostomidæ), a few mollusks (Planorbis, young Unios and thin-shelled Anodontas), and some Aselli complete the brief dietary of this group.

It is not until we examine the food of full-grown specimens that we wholly appreciate the utility of the enormous crushing pharyngeal jaws with their pavement teeth, found in this species. The entire food of the three large specimens examined, taken at Peoria, in April and October, proved to consist of mollusks only, including forty-six per cent. of the thick and heavy water snail, *Melantho decisa*, whose shell probably no other fish in our rivers could break. Cyclas, Anodonta and indeterminable Gasteropoda composed the remainder of the food.

ON THE FOOD OF YOUNG FISHES.

BY S. A. FORBES.

I cannot learn that anything has been recorded respecting the food of young fishes in this country,* nor have I been able to find anything upon this subject in such part of the ichthyological literature of Europe as is accessible to me. From the lack of all mention of the use of Entomostraca as the food of young fishes in the general review of the relations of these Crustacea to organic nature given by Gerstaecker in Bronn's Thier-Reich† I infer that whatever systematic investigation the subject may have received, the results have not attracted any general attention.

This seems a surprising fact when one considers the vast amount of labor which has been expended upon this class of animals, and reflects for a moment upon the interest to science and to practical fish-culture of a knowledge of the food resources of fishes and of the competitions of the various species in the search for subsistence.

Although I cannot yet treat this subject as fully as it deserves, the results of such study as I have been able to make, during the past season, of the contents of the stomachs and intestines of small specimens, seem to justify this preliminary notice.

It was early apparent, in the course of the investigation, that the food of many fishes differs greatly according to age; and it was soon found that the life of most of our fishes divides into at least two periods, and of many into three, with respect to the kinds of food chiefly taken. Further, in the first of these periods, a remarkable similar-

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*Perhaps exception should be made of a note relating to the occurrence of diatoms in the stomachs of two young whitefishes, published in the appendix to the Report of the U. S. Fish Commissioner for 1872-3, p. 57.

†Classen und Ordnungen des Thier-Reichs, Band V., Abtheilung 1, ss. 750 u. 1057.

ity of food was noticed among species and families whose later food-habits are widely different.

The full-grown black bass, for example, feeds principally on fishes and crawfishes, the sheepshead on mollusks, the gizzard-shad on mud and Algæ, while the catfishes are nearly omnivorous; yet these are all found to agree so closely in food when very small that one could not possibly tell from the contents of the stomachs which group he was dealing with.

It is my purpose in this paper to give what facts I have relating to the food of our fresh-water species during this first period of the fish's life. These facts were derived from the examination of one hundred and twenty-six specimens, ranging from three-eighths of an inch in length up to an inch and a half, and in a few cases to two and three inches. These specimens belong to twenty-four genera and represent eleven families. In two or three genera none were obtained small enough to be regarded as belonging strictly to this first food-period, but the earliest food is nevertheless plainly inferable; and the general distribution and variety of the species studied is such that I think the main conclusions will be found to stand the test of full investigation. As the first period is evidently much shorter with some species than with others, and doubtless varies in the same species according to situation and circumstances generally, of course no common limit of size could be set up, but the smallest specimens of each species were selected until a size was reached where a marked difference of food appeared.

Acanthopteri.

Although the young Acanthopteri have already been discussed in the preceding paper on the food of that group, it will be convenient to review the facts concerning these young fishes for the purpose of comparing their food with that of the other orders.

The food of six *common perch* (*Perca americana*), from an inch to an inch and a quarter long, consisted wholly of Entomostraca and larvæ of Chironomus,—eight per cent. Chironomus, fifty-two per cent. Cladocera, and forty per cent. Copepoda.

No very small Labracidæ were found, the youngest being a Morone an inch and a quarter long. Half of the food of this consisted of Entomostraca (chiefly Cladocera), and the other half was minute gizzard-shad.

A group of forty-three sunfishes (Centrarchidæ), from five-eighths of an inch to two inches long, was made up as follows:—of five specimens of Micropterus under three-fourths of an inch long, two of Ambloplites of the same size, two of Chænobryttus from seven-eighths of an inch to one inch, one of Apomotis an inch in length, nine of Lepiopomus from an inch to an inch and a fourth, nine of Eupomotis from one and a half to two inches, five of Centrarchus one inch and under, four of Pomoxys from three-fourth of an inch to an inch and a half, and six indeterminable specimens, probably Lepiopomus, from seven-sixteenths to five-eighths of an inch long. Ninety-six per cent. of the food of these forty-three specimens consisted of Entomostraca and larvæ of Chironomus,—seventy of the first and twenty-six of the second,—the trivial remainder consisting of Neuroptera larvæ and young Amphipoda with traces of water mites, Corixas and mollusks (the last in Eupomotis). The Entomostraca were forty-two per cent. Cladocera, nineteen per cent. Copepoda and nine per cent. Ostracoda.

A single Haploidonotus an inch and an eighth in length, had eaten Chironomus larvæ (seventy-five per cent.) and larvæ of *Palingenia bilineata*.

Esocidæ.

I did not have the good fortune to obtain any young of the common pike, and can only report on the food of a single *Esox salmoneus* an inch and a fourth in length. This specimen, taken at Pekin, Ill., on the 2d of June, had already begun its life labor of the elimination of little fishes, these making about two-fifths of its food. The remainder consisted of Crustacea, composed about equally of young Amphipoda, Daphniidæ and Lynceidæ. The presence of so large a quantity of these minute Entomostraca in the stomach of a pickerel of this size, is sufficient evidence that they form the principal part of its food at an earlier age.

CLUPEIDÆ.

We come next to twelve specimens of the *gizzard-shad* (Dorysoma), whose minute fry swarm in countless numbers in the waters of our larger rivers in midsummer. These were taken in June and July, from the Illinois R., from Ottawa to Peoria. The smallest of the group were twenty mm. long by two mm. wide,—as slender as cyprinoids and nearly cylindrical, although the adult is a high, thin fish. I was greatly interested by the discovery that the maxillaries of these smallest specimens are provided with teeth, —a single row of nine or ten on the lower edge,—although the mouth of the adult is entirely toothless and smooth. The internal structure also differs remarkably from that of the adult, especially in the much greater simplicity of the digestive apparatus. In a young gizzard-shad seven-tenths of an inch long by one-tenth high, the intestine was found to pass from the anterior end of the stomach to the vent with only one short forward turn of about a fourth the length of the body cavity, made a little way behind the stomach. Although the mucous surface of the intestine was at this time very rugose, showing a commencing complication of the digestive system, there was no trace of pyloric cœca. The intestine was filled with Cypris, Chydorus, Alona, Cyclops, etc.

On the other hand, in a fish three and three-fourths inches long, showing the general characters of the adult, the intestine passed upward and backward from its origin, running without flexure the whole length of the body cavity (this part being covered with an immense number of pyloric cœca), then turned forward to the stomach, ran back from there about one-third of the way to the vent, then turned forward and ran a tortuous course beneath the stomach to the pericardial membrane and back again, also tortuously, two-thirds of the way to the vent. From this point it ran forward again to the stomach, and crossing to the left side, ran repeatedly backward and forward in the posterior part of the body cavity, making seven turns between the stomach and vent before opening, thus extending, in all, about eight times the length of the perivisceral cavity. This intestine was well filled with mud with only a slight sprinkling of unicellular Algæ.

Much as these young resemble young Cyprinidæ, they can be easily distinguished from them by the very long anal fin; and from the brook silversides (Labidesthes), to which they bear some superficial resemblance, by the absence of a spinous dorsal.

These twelve fishes, all under two inches in length, had eaten about ninety per cent. of Entomostraca, two per cent. of Chironomus larvæ, and for the remainder, Algæ. The Crustacea were about equally Cladocera and Copepoda. Among the former were *Daphnia pulex*, *Simocephalus americanus*, *Ceriodaphnia dentata*, Bosmina, Chydorus and Alona. In a specimen three-quarters of an inch long which I took from the stomach of a *Morone interrupta*, I found a few specimens of *Leptodora hyalina* (?) Lillj. The Copepoda were all Cyclops, so far as recognizable.

Cyprinidæ.

A single minute minnow, three-eighths of an inch long, which I could not determine specifically, had eaten Daphnids (twenty-five per cent.) and Chironomus larvæ.

The specimens of the common *chub minnow* (*Semotilus corporalis*), ranging from five-eighths inch to one inch, indicate somewhat doubtfully an exception to the general rule respecting the early food of fishes. Only seven per cent. of their food was Entomostraca, and the whole remainder consisted of filamentous Algæ. It should be noted, however, that twenty per cent. of the food of the smallest specimen, which was five-eighths of an inch long, was Cyclops, and it may be that Semotilus lives wholly on Entomostraca at first, merely changing its habit earlier than most of its allies.

Two specimens of *Notropis*, an inch and a half in length, had eaten nothing but Daphnids.

Catostomidæ.

Thirty specimens, representing five genera of this peculiar family, were studied. A very curious feature of the food of the young is the frequent dependence of suckers of considerable size—six inches long or more—upon food more trivial than Copepoda or Lynceidæ; viz., upon rotifers, Protozoa and unicellular Algæ. While only such Protozoa were found as are furnished with firm tests or carapaces, yet the abundance of Difflugia and Arcella in the intestines of these fishes leaves little doubt that the more perishable Protozoa must also be taken in considerable quantity. It is an interesting fact that even here the smallest specimens were found feeding on Entomostraca only, and it is therefore possible that these form the first food of the family.

Ten specimens of the *stone-roller* (*Hypentelium nigricans*), ranging from one and three-eighths to three inches, represent two dates and localities. The four smallest, none larger than an inch and three-fourths, were taken from the lower Fox, July 9, 1879. The others were obtained from Mackinaw Cr., in Woodford Co., Ill., in the latter part of August. The situations were similar, both streams being swift and rocky where these fishes were caught. Their food was chiefly the larvæ of Chironomus (ninety per cent.), the remaining tenth being principally made up of Alona (six per cent.). Ostracoda, Copepoda, and Algæ each made about one per cent. of the food. The Algæ were mostly diatoms and desmids, Closterium being especially common. Many Difflugia and Arcella were also found in these fishes.

We trace in this a remarkable resemblance to the food of the darters, which, it will be remembered, frequent similar situations. Lacking the sucking mouth of Hypentelium, they do not take Protozoa or unicellular Algæ, but in other particulars agree closely with this species. This curious fish is peculiar among the suckers in the unusual development of the pectoral fins,—a distinguishing feature of the darters likewise,—doubtless related, in both cases, to the constant struggle with a swift current. We may also remark the darter-like glow of color in the young of this species,—a very peculiar distinction among the Catostomidæ. This is one among many facts which indicate that exposure to light has great primary effect on the color of fishes,—an effect often suppressed, through natural selection, by secondary influences, but manifesting itself where these are not brought into play.

This species is in marked *contrast* with the darters, not only in the rapidity of its growth and the ultimate size attained, but in the form and size of the head, which in the darters is small and pointed, but in these fishes is unusually large, square and strong.

The principle of adaptation has here resulted in a different line of development. While the little Etheostomatidæ have become fitted to slip and pry about beneath the stones for their food, Hypentelium has acquired the power of rolling the stones before it. As it grows larger, it resorts, of course, to deeper water, but always prefers the rocky reaches of the stream. The moulding power of natural selection could scarcely have a better illustration than that afforded by the adaptive characters, both similar and dissimilar, of these two widely separated groups of fishes.

A single specimen of *black sucker* (*Minytrema melanops*) was too large properly to come within this group; but, although six inches long, most of its food was Cyclops (eighty per cent.). Other items were Alona, Difflugia, Closterium and very young Uniones.

Four *chub-suckers* (*Erimyzon sucetta*), two of which were three-fourths of an inch, and two an inch and a quarter long, differed greatly in food from the foregoing. The two smaller specimens, from Long L., near Pekin, taken June 2, 1880, had eaten only Cladocera, with a trace of water mites. Chydorus was the principal element of their food (eighty per cent.), but Pleuroxus, Alona and *Scapholeberis mucronata* were also present. In the two larger specimens, locality and date unknown, a surprising number and variety of the minutest animal and vegetable forms were found. Squamella, Anuræa of several species, *Rotifer vulgaris* and other Rotifera; Difflugia and Arcella* among the Protozoa; Chroöcoccus, Closterium, Cosmarium,

*Slides of the food of this genus and Myxostoma were submitted to Dr. Jos. Leidy, of Philadelphia, and Prof. W. S. Barnard, of Cornell University, N. Y., and these gentlemen kindly sent me the following names of Rhizopoda as occurring therein: From Prof. Barnard, *Difflugia acuminata, pyriformis, constricta* and *globosa*; from Dr. Leidy, *D. pyriformis, acuminata, globulosa, lobostoma* and *Arcella vulgaris* and *discoides*.

Staurastrum and various diatoms among the Algæ, were the principal genera. A minute Agrion larva, a very young Amphipod, and larval Copepoda (nauplius), were the only other kinds recognized. It was obviously impossible to make any estimate of the ratios of such minute and varied objects occurring in such great quantity, and I have contented myself with a simple enumeration.

A specimen three inches long, from Peoria Lake, in October, had eaten only Copepoda (Canthocamptus) with a trace of Chironomus larvæ.

Ten specimens of *red-horse* (Myxostoma), varying in length from an inch to two and three-fourths, taken in July and August, from the Fox and Illinois rivers and from Mackinaw Cr., show no important differences of food.

In the smaller specimens, taken from the Fox and Illinois, Entomostraca, especially Cyprids, were relatively more important, sometimes constituting nearly the whole food; but no attempt was made to fix precise ratios. In the four larger specimens from Woodford Co., tests of Difflugia were estimated to form eighty-five per cent. of the contents of the intestines. These specimens were taken one at a time, several miles apart, along a rocky part of the stream. Besides the species of Difflugia and Arcella given in the foot-note, various desmids and diatoms were abundant, with filamentous Algæ, rotifers (Squamella and *Rotifer vulgaris*), Cyclops, Alona, Pleuroxus and water mites, Chironomus and other Diptera larvæ, some indeterminable vegetable matter and a single Thrips (Hemiptera). The small percentage of Chironomus larvæ shows that this species has not the habit of the stone-roller.

Two specimens of the *common sucker* (*Catostomus commersonii*), six inches and six and three-fourths in length, taken from Mackinaw Cr., in August and June, had eaten food so similar to that of the preceding genus that detailed description is unnecessary.

Two specimens of the commonest *buffalo-fish* (Ichthyobus), seven-eighths of an inch long, had eaten most freely of unicellular Algæ (sixty-three per cent.), of which only Protococcus and Closterium were recognized. Specimens of Anuræa were reckoned at twenty-seven per cent., and the remainder of the food consisted of Copepoda and Cladocera. These specimens were taken from the Illinois R. in early June.

Four *carp-suckers* (Carpiodes), seven-eighths inch to two inches long, taken from the Illinois and from Clear L., in Kentucky, had fed like the preceding genus, except that the Entomostraca were in larger quantity (forty-eight per cent.), and included a number of Ostracoda, while the rotifers were comparatively few. The Daphniidæ of the Illinois R. specimens were nearly all *Scapholeberis mucronata*. Canthocamptus in trivial numbers was also found in a single specimen.

Reviewing the food of these thirty young suckers, we see that they differ from the other families studied in the larger food-resources open to them; for, while the structure of their mouths does not prohibit their taking Entomostraca, it enables them to draw upon the multitudes of minute organisms found upon the bottom. Evidently they have no means of selecting such microscopic structures from the mud in which these most frequently rest, and considerable quantities of dirt are consequently often found in the intestines; but from the "richness" of the contents I infer that they doubtless have the power of distinguishing mud containing a large percentage of organic matter from relatively barren portions.

Siluridæ.

Numerous specimens of the young of this family show that, notwithstanding its many peculiarities of structure and habit, it is no exception to the general rule respecting the food of the young. The smallest of these specimens were from a little school of minute fry, taken in June from the friendly protection of an old oyster-can in the Illinois R. These little creatures were colorless and seemingly almost helpless, and only three-eighths of an inch in length. They had already begun to eat, however, and their stomachs were well filled with Cyclops and a few Daphnids and Chironomus larvæ. These were certainly Amiurus, but it was of course impossible to tell the species.

Other specimens of this genus, making thirteen in all, none longer than an inch and five-eighths, were obtained from various places on the Illinois, and from mud-holes in the Mississippi bottoms, in Union Co. These thirteen individuals were feeding almost wholly on Entomostraca and larvæ of Chironomus, the latter composing seventy-four per cent. and the former eighteen per cent. of their food. Twenty-two per cent. of Cladocera include *Simocephalus americanus* and *S. vetulus*, Ceriodaphnia, and *Macrothrix laticornis*,* Jur., a species not hitherto reported from this country. Among the Lynceidæ (ten per cent.) I recognized Chydorus, *Pleuroxus dentatus*, Alona and *Eurycercus lamellatus*, and among the Ostracoda a species of Candona answering precisely to the description of *Candona bifasciata*, Say. A few young Amphipoda and a few unknown insects' eggs account for the remainder of the food.

Six specimens of *Noturus sialis*, varying in length from seven-eighths of an inch to an inch and a quarter, differed from the foregoing in the much larger proportion of Chironomus larvæ (forty-one per cent.) and in the twenty-six per cent. of young *Allorchestes dentata*,— eaten by the larger specimens. These had also taken seven per cent. larvæ of Ephemeridæ. Those under an inch in length were peculiar only in the large ratio of Chironomus larvæ (sixty-five per cent.), a fact probably indicating that this species seeks its food chiefly on the muddy bottoms.

No specimens of the other genera of catfishes were taken small enough to show their earliest food, but so far as can be judged from the food of four specimens of Ictalurus, from two and a half to three and a half inches long, the other genera will not be found to differ especially from the foregoing.

Amiidæ.

A single dog-fish (Amia), one and three-fourths inches long, taken in June, had eaten seventy per cent. of Entomostraca,—about equally Copepoda and Cladocera,—and

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*Possibly this is not the species cited, but a careful comparison with the description and figures in Lilljeborg's "Crustacea ex Ordinibus Tribus," etc., failed to show any difference.

two per cent. of larvæ and pupæ of Chironomus. A few young Allorchestes and some Corixas complete the brief list.

Several specimens of Amia under one inch in length, whose anatomy I studied three years ago, I remember to have had their intestines packed with Entomostraca.

Lepidosteidæ.

Here also I shall have to content myself with such hints of the food of the young as are given by two or three specimens, as the youngest are not yet common enough in our collections to supply more material for a study of their food. One of the two smallest gars examined, an inch and a fourth in length, taken in June, near Peoria, had filled itself with *Scapholeberis mucronata*, and the other had taken only a minute fish. A specimen two inches long and only an eighth of an inch in depth, furnished a striking illustration of the voracity of this terror of our streams, as its stomach contained sixteen minute Cyprinoids.

Summary.

A sufficient recapitulation of the foregoing data is afforded by the appended table of the food of the different genera. It may be worth while to say that all the material upon which the foregoing statements rest, as well as all that used in the preceding paper, has been carefully preserved, and may be seen at any time by those interested, at the State Laboratory of Natural History.

The general conclusion from these observations is the supreme importance of Entomostraca and the minute aquatic larvæ of Diptera as food for nearly or quite all of our fresh-water fishes,—a conclusion that gives these trivial and neglected creatures, of whose very existence the majority of the people are scarcely aware, a prominent place among the most valuable animals of the state, for without them all our waters would be virtually depopulated. Other facts of eminent interest thus brought to view are the magnitude and intensity of the competition for food among the young of all orders of fishes, where a stream is fully stocked, and the injurious character of such a species as the shovel-fish, which feeds on Entomostraca throughout its life. It is probable that all fishes which are not especially adapted to the food requirements of the more valuable fishes, are hurtful to them, because they limit the food available for the young. The sunfishes, whose shape protects them from many enemies, and the catfishes, with their armor of poisoned spines, are instances in point While their young compete with the young bass and wall-eyed pike for food, they do not furnish the latter any important food resource in later years. On the other hand, such species as the herbivorous minnows and the cylindrical suckers, which depend upon Entomostraca to a less extent when young, or take up other food at a relatively early period, are those which seem to promise best as food for the higher fishes.

It is a curious corollary from the above reasoning that a prolific species having an abundant food supply, and itself the most important food of predaceous fishes, may, by extraordinary multiplication, so diminish the food of the young of the latter as to cause, through its own abundance, a serious diminution of the numbers of the very species which prey upon it. To put this statement into more concrete form, it is not certain that the excessive increase of the gizzard-shad, for instance, would be a benefit to the black bass and pike-perch which feed so largely upon it. In fact, it is clear that the great overstocking of a stream with gizzard-shad would, by eventually reducing the supply of Entomostraca, cause a corresponding reduction in the numbers of all the species of that stream by starvation of the young; and this decimation, applying to all in the same ratio, would take effect upon the *ordinary* number of the other species, but upon the *extraordinary* number of the gizzard-shad,—would reduce the other species below the usual limit, but might not even cut off the *excess* of the shad above that limit. Consequently, important as is the supply of food fishes for the predaceous species, it is not less important that the predaceous species should be supplied to eat up the food. Here, as elsewhere, only harm can come from an imperfect balance of the forces of organic nature, whether the excess be upon one side or the other.

In the effort to increase the valuable fishes of a lake or stream, it is not sufficient that the food of these species should be increased alone, but at the same time special measures must be taken to secure a corresponding multiplication of the predaceous fishes themselves, otherwise precisely the reverse result may be produced from that intended.

As a further illustration of some of the practical bearings of these facts, it may be noticed that the free access of fishes to the ponds, lakes and marshes connected with a stream is a matter of the highest importance. Running water is relatively destitute of Entomostraca, and hence fishes denied access while breeding to slow or stagnant water in which Entomostraca abound, have no chance to multiply. The condition of fish life in the lower Fox R. will illustrate this point. This stream takes its rise in the numerous lakes of northwestern Illinois and southern Wisconsin, but in its lower course has few branches and no stagnant waters draining into it. Its own current is swift and much of its bed is rocky, while the vast expanse of water of which it forms the outlet prevents any great oscillations of its level with the consequent flooding of adjacent lands. This part of the stream is therefore peculiarly unfit for breeding purposes, and we should expect few fish to maintain themselves in it if denied access to the immense and teeming breeding grounds of the upper part of the river. Such access is effectually cut off by several dams, unprovided with fishways, which have been thrown across the stream. A fish which enters the river from above therefore cannot get back to breed,—a fact which must unfavorably affect the number of fishes in both river and lakes, and is apparently one cause of an unusual scarcity of game fishes in that stream.

Table of Food of Young Fishes.

	Perca.	Morone.	Centrarchidæ*	Haploidonotus.	Esox.	Dorysoma	Cyprinidæ, sp.	Semotilus.	Notropis.
Number of specimens..	6	1	43	1	1	12	1	3	2
Size in inches	1@ 1¼	1¼	⅝@ 2	1⅛	1¼	½@ 1¾	⅜	⅝ @1	1½
Kinds of Food.	Ratios in which each element of food was found.								
I. Fishes................	....	50	....	....	40	....	....	....	....
Dorysoma..................	....	50	....	....	....	....	....	....	....
II. Mollusks............	....	....	†	....	....	....	....	....	....
III. Insects...............	08	....	28	100	....	02	75	....	....
1. *Diptera* (larvæ)...........	08	....	26	75	....	02	75	....	....
Chironomus...............	08	....	26	75	....	02	75	....	....
Corethra..................	....	....	....	....	....	†	....	....	....
2. *Hemiptera* (young)........	....	....	†	....	....	....	....	....	....
Corixa...................	....	....	†	....	....	....	....	....	....
3. *Neuroptera* (larvæ)........	....	....	02	25	....	....	....	....	....
Ephemeridæ..............	....	....	....	25	....	....	....	....	....
Palingenia..............	....	....	....	25	....	....	....	....	....
IV. Hydrachnidæ.......	....	....	†	....	....	....	....	....	....
V. Crustacea............	92	50	72	....	60	90	25	07	100
Amphipoda (young)	....	....	02	....	20	....	....	....	...
Entomostraca...............	92	50	70	....	40	90	25	07	100
Cladocera................	52	40	42	....	40	42	25	....	100
Sididæ.................	....	....	02	....	....	....	....	....	....
Daphniidæ..............	50	....	36	....	20	34	25	....	100
Lynceidæ..............	02	....	04	....	20	04	....	....	....
Leptodoridæ............	....	....	....	....	....	02	....	....	....
Ostracoda................	....	....	09	....	....	†	....	....	....
Copepoda.................	40	10	19	....	....	48	....	07	....
VI. Algæ	....	....	....	....	....	08	....	93	....

* For detailed tables of the food of the young of this family see the preceding paper on the food of the Acanthopteri.

TABLE OF FOOD OF YOUNG FISHES—Continued.

	Hypentelium.	Erimyzon.	Myxostoma.	Ichthyobus.	Carpiodes.	Amiurus.	Noturus.	Amia.	Lepidosteus	TOTAL.
Number of specimens....	10	4	10	2	4	13	6	1	2	126
Size in inches...........	1⅜ @3	¾@ 1¼	1@ 2¾	⅞	⅞@ 2	⅜@ 1⅝	⅞@ 1¼	1¾	1¼	
KINDS OF FOOD.	Ratios in which each element of food was found.									
I. FISHES.............	....	....	...	....	....	....	....	....	50	...
II. INSECTS..........	90	11	†	....	....	22	58	25	....	...
Eggs.	....	04	....	....	....	....	....	.. ..	....	...
1. *Diptera* (larvæ).......	90	....	†	....	....	18	41	10	....	...
Chironomus...........	90	....	†	....	....	16	41	10	....	...
2. *Coleoptera* (larvæ)	....	....	....	....	....	....	10	....	....	...
3. *Hemiptera*...........	†	†	†	....	....	...	...	15	....	...
Corixa	....	....	....	....	....	....	....	15	....	...
4. *Neuroptera* (larvæ)....	†	07	..	....	....	....	07	....	....	...
Ephemeridæ..........	†	04	....	....	....	....	07	....	....	...
III. HYDRACHNIDÆ...	†	03	†	....	....	....	....	....	....	...
IV. CRUSTACEA.......	09	51	†	10	48	78	40	75	50	...
Amphipoda (young).....	....	†	....	.....	...	04	20	05	....	...
Entomostraca	09	50	†	10	48	74	15	70	50	...
Cladocera.............	07	49	†	05	23	22	06	35	50	...
Daphniidæ..........	01	02	....	....	23	11	....	35	50	...
Lynceidæ...........	06	47	†	....	....	10	06	....	.....	...
Ostracoda.............	01	01	†	....	15	12	....	....	....	...
Copepoda.............	01	†	†	05	10	40	09	35	....	...
V. ROTIFERA.	....	....	†	27	†	....	....	....	....	...
VI. PROTOZOA........	†	15	†	....	†	....	....	....	....	...
VII. ALGÆ	01	20	†	63	52	...	02	....	....	...

THE FOOD OF BIRDS.

BY S. A. FORBES.

Excluding the inhabitants of the great seas, birds are the most abundant of the Vertebrata, occupying in this great subkingdom the same prominent position that insects do among invertebrate animals. These two classes thus constitute exceptions to the general rule that the higher and more active animals of each group are the less abundant,—a fact doubtless largely due to the immense advantage given them by their power of flight. It is this which, by making migration possible, enables birds to choose their climates and their seasons,—thus avoiding, in a great measure, one of the most destructive checks upon the multiplication of animals. Their disproportionate number, their universal distribution, the remarkable locomotive power which enables them readily to escape unfavorable conditions, and their immense activity and higher rate of life, requiring for their maintenance an amount of food relatively enormous, give to birds in their relation to the pursuits and interests of man a significance which only here and there one seems ever fully to have realized. A few figures will illustrate and enforce this proposition.

The careful estimates of three ornithologists and experienced collectors give, as an average of the whole bird-life of Illinois, three birds per acre during the six summer months. That is to say, if all the birds of the year, except the swimmers, were concentrated in these six months, equally distributed throughout them and equally scattered over the state, we should have three birds on every acre of land. It is my own opinion that about two-thirds of the food of birds consists of insects, and that this insect food will average, at the lowest reasonable estimate, twenty insects or insects' eggs per day for each individual of these two-thirds, giving a total for the year of seven thousand two hundred per acre, or two hundred and fifty billions for the state—a number which, placed one to each square inch of surface, would cover an area of forty thousand acres.

Estimates of the average number of insects per square yard in this state gives us, at farthest, ten thousand per acre for our whole area. On this basis, if the operations of the birds were to be suspended, the rate of increase of these insect hosts would be accelerated about seventy per cent., and their numbers, instead of remaining year by year at the present average figure, would be increased over two-thirds each year. Any one familiar with geometrical ratios will understand the inevitable result. In the second year we should find insects nearly three times as numerous as now, and, in about twelve years, if this increase were not otherwise checked, we should have the entire state carpeted with insects, one to the square inch over our whole territory. I have so arranged this computation as to exclude the insoluble question of the relative value of birds and predaceous or parasitic insects, unless we suppose that birds eat an undue *proportion* of beneficial species.

This is intended only as an illustration of the great power of birds for good or evil, and not as a prediction of the consequences of their total destruction. These consequences would not be by any means so simple, but would apparently be fully as grave.

Let us take another view of this matter. According to the computation of our first State Entomologist, Mr. Walsh, the average damage done by insects in Illinois amounts to twenty million dollars a year. These are large figures, certainly; but when we find that this means only about fifty-six cents an acre, we begin to see their probability. At any rate, few intelligent farmers or gardeners would refuse an offer to insure complete protection, year after year, against insects of all sorts for *twenty-five* cents an acre per annum; and we will, therefore, place the damage at one-half of the above amount—ten million dollars per annum.

Supposing that, as a consequence of this investigation, we are able to take measures which shall result in the increase, by so much as one per cent., of the efficiency of birds as an insect police, the effect would be a diminution of the above injury to the amount of sixty-six thousand dollars per annum, equivalent to the addition of over one and one-half million dollars to the permanent value of our property; or if, as is in fact a most moderate estimate, we should succeed in increasing the efficiency of birds five per cent., we should thereby add eight and one-fourth million dollars to the permanent wealth of the state, provided, as before, that birds do not eat unduly of beneficial species.

These figures will be at once rejected by most naturalists as absurdly low. The young robin of Prof. Treadwell (a bird whose fame has extended over both hemispheres) required not less than sixty earthworms a day to keep it alive. A pair of European jays have been found, Dr. Brewster informs us, to feed their brood half a million caterpillars in a season, and to eat a million of the eggs in a winter. I have myself taken one hundred and seventy-five larvæ of Bibio from the stomach of a single robin, and the intestine probably contained as many more.

Compared with these numbers, my two thousand four hundred insects a year for each bird seem certainly many times too few; and similar criticisms might very probably be made on other items of the estimate. I prefer, however, to put these matters with a moderation which will command general assent, especially as we see that the importance of the subject does not require exaggeration. Of course the individual farmer or gardener could, by intelligent and careful management, if he knew just what to do, increase the value of his own birds far beyond his individual share of the above-mentioned aggregate.

The subject has, also, a considerable scientific interest. Since the struggle for existence is chiefly a struggle for subsistence, a careful comparative account of the food of various competing species and genera, at different places and seasons and at all ages of the individual, such as has not heretofore been made for any class of animals, cannot fail to throw much light upon the details, causes and effects of this struggle. The flexibility of the food-habits of the widely ranging species, the direct effects of normal departures from the usual average of food elements upon the origin of variations, and the general reäctions of birds upon their organic environment, are examples of subjects upon which light should be thrown by this investigation.

That an element of such transcendent importance to all agricultural pursuits, and, through these, to the general welfare, ranking evidently among the larger forces of nature which affect powerfully and continuously the most essential interests of the country, should never have been made the subject of continuous, systematic and accurate study, seems, at first, a surprising phenomenon. It is a subject, however, presenting few attractions to the scientific student, requiring a great amount of time, a good knowedge of ornithology, a minute acquaintance with considerable parts of entomology and botany, and a good degree of skill with the microscope, while it profits the student but slightly relatively to the work done, by way of an increase of his knowledge. What little he learns is gained at every disadvantage. His material is in the worst possible condition for study; and the personal result of his labor is a continual discouragement to him. That whatever individual impulse should have been turned in this direction should have been exhausted long before definite or conclusive results were reached, was, therefore, inevitable. The student soon turned his attention to matters more attractive and more fruitful in knowledge and reputation. In short, this is emphatically one of those questions which, if studied exhaustively at all, must be studied chiefly in the public interest.

The primary purpose of this investigation is the determination of the exact relation of the different species of birds, and of the class in general, to agriculture and horticulture; it would be disgraceful to those in charge of this investigation if the opportunity were to be thrown away which it offers for an increase of that knowledge of the habits and relations of birds whose interest is strictly scientific rather than practical, and this has therefore been held in mind throughout as a legitimate secondary purpose. We need a full knowledge of the direct and indirect benefits and injuries attributable to each species,—the ratio of benefit to injury, where both are apparent, the numbers, distribution and migrations of all, and, in fact, a full acquaintance with their entire natural history.

The direct injuries due to birds commonly take the form of depredations upon the fruits of the garden and orchard, and upon the grain in the fields. It is, of course, necessary to know the species chargeable with these, and the ratio which such injuries bear to the benefit likewise attributable to them. The good done by birds is almost wholly indirect, consisting chiefly in the destruction of insects which would become directly or indirectly injurious if allowed to live. Much of the apparent evil for which they are held responsible is also indirect; viz., the destruction of parasitic and predaceous insects which, if not destroyed, would help to diminish the numbers of injurious species. I wish, however, to call especial attention to the fact that *the regular and continuous destruction of parasitic and predaceous insects by birds is not necessarily an evil.* Paradoxical as this statement may seem, it is fully borne out by the following facts:—

The most serious losses of the farmer and gardener due to insects are not consequent upon the ordinary and uniform depredations of those species whose numbers remain nearly constant, year after year, but upon excessive and extraordinary depredations of those whose numbers are subject to wide fluctuations. Vegetation has become so far adjusted to our crickets and ordinary grasshoppers, etc., that the foliage they eat can be spared without injury to the plant, and the damage done by them is commonly imperceptible.* It is far otherwise, however, with the vast hordes of the Rocky Mountain locust, of the Colorado potato-beetle, of the chinch-bug and of the army-worm, and many other species which occasionally swarm prodigiously and then almost disappear from view. The injurious species are chiefly the oscillating ones, and the dangerous species are those which show a tendency to oscillate. Anything which tends to limit the fluctuations of an oscillating species, or to prevent the oscillation of a stable species is, therefore, highly useful, while anything which tends to intensify an oscillation, or to convert a stable species into an oscillating one, is as highly pernicious.

Now a species is stable because the rate of its reproduc-

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†See Kirby and Spence's Introduction to Entomology, 4th ed., 1822, Vol. I., pp. 247-258.

tion is uniform, because the checks upon its increase are substantially unvarying, and because these two forces balance each other. To set up any vibration in any one of these checks, will necessarily cause a corresponding vibration in the number of the species limited by it. More explicitly, to set up an oscillation in a predaceous or parasitic species must produce a reverse oscillation in the species parasitized or preyed upon. As the former increases, the latter must diminish, and *vice versa*. But either a marked decrease or a marked increase of a species will cause it to oscillate, unless made with extreme slowness,—a slowness so extreme as to allow progressive adjustments of all kinds to keep pace with it.

Taking a predaceous beetle as an example, we see that a rapid decrease of its numbers, partly relieving the species which it preys upon from one of the usual checks upon its multiplication, will affect an increase in those species,—will thus render the food of the predatory insect more abundant. This will, in turn, faciliate individual maintenance of the predatory insect and thus stimulate reproduction, initiating a forward movement, which, proceeding at a geometrical ratio, must continue until the predaceous species becomes too numerous for its food, or reaches other limitations; when destruction of the excess produced will send it back below the average line again. An oscillation will thus necessarily arise which must be reproduced in the food species connected with it.

On the other hand, if the predaceous species be suddenly increased in number by a diminished power or stringency in one of its accustomed checks, the process will simply be reversed, but the resulting oscillation will be the same. The predaceous species will increase geometrically until its food supply becomes insufficient for it, then by starvation and diminished reproduction it will be again reduced, and so on indefinitely. *Any* marked disturbance of a *fixed adjustment* between the rate of reproduction and the death rate, whether it result in increase or decrease, whether it affects a beneficial or an injurious species, is, therefore, in itself, an *immediate* evil; only to be incurred where the ultimate good is a certain and liberal compensation.

Again, it is becoming evident that carnivorous insects and insectivorous birds all have their food-preferences. Probably no one species—certainly no one family—of birds or insects would quite take the place of another. Supposing, then, that some birds eat predaceous insects, in part, as well as phytophagous ones,—eat the former, perhaps, in undue ratio—still, as the chances are practically infinite that the predaceous insects it eats would not, if allowed to live, eat precisely the same amount and kind of injurious insects as the bird itself, by destroying the bird we should merely liberate a second cause of numerous oscillations. Those species neglected by the carnivorous insects would increase beyond their bounds, and those eaten by them would be unduly diminished. It follows from the foregoing reasoning that, as a general rule, *a bird should not be discredited for the regular and established habit of destroying predaceous or parasitic insects*, unless it can be shown that those insects would, if left to themselves, check the fluctuations of some injurious species, or afford a better safeguard against the possible fluctuations of others. It must also be shown that this prospective good will not be overbalanced by some greater evil. In short, the whole burden of proof is on the side of those who would disturb the fixed order of Nature.*

The most important question respecting the relations of birds to insects is, therefore, the determination of those species of birds which serve the most useful purpose as a *constant* check upon those insects which are either injurious or capable of becoming so if they appear in largely increased numbers. Fortunately, whatever oscillations or irregularities may arise, and whatever may be their cause, the general tendency of things is towards their correction. In course of time, if new disturbances do not continually unsettle even the newest arrangements, they will usually right themselves more or less completely. The methods

*For a discussion of the general subject, see Herbert Spencer's Principles of Biology, Vol. 2, Pt. VI., Chap. II., p. 397; and the preceding paper, "On Some Interactions of Organisms."

of this spontaneous restoration of the unsettled balance of natural forces, are, of course, worthy of the most careful study. It is only by working in harmony with them that we ourselves can help to reädjust the disturbed order. A fuller treatment of this matter may best be postponed until the general discussion of results obtained by the investigation. Enough has been said to show that the subject, although complicated and difficult, will richly repay the study necessary to its mastery. A full and accurate knowledge of the mutual relations of the various forms of organic life of a region, both normal and abnormal, is certainly quite as essential to the general welfare as a knowledge of the chemistry and geology of its soils, the peculiarities of its meteorology, or any other part of the inorganic environment.

Concerning the special subject of this paper, the knowledge we need is such that we shall be able to afford for every species a tolerably correct answer to the questions, What would be the main consequences if this species were exterminated? if it were reduced to half its present numbers? What if it were doubled in number? if it were quadrupled? When this is known, we shall evidently be able to act wisely and with the best results. That these questions are not unanswerable, I shall undertake to prove by answering them in substance, for several species, in this paper, and by demonstrating the sufficient accuracy of the answers.

Methods.

Three methods are possible in determining the food of birds. The birds may be fed in confinement, and the kinds of food apparently preferred and the amount eaten may be noted. This evidently shows only what the bird *will* eat when restrained of its liberty, of such food as may be placed before it, and furnishes few data which we can use with safety in making up an account of its food in freedom, when foraging for itself. The state of confinement is so abnormal for a bird that on this account, also, we can rarely reason from its habits in that state to its ordinary habits. This method is, therefore, available only for the solution of a few separate questions. A far more useful method, and, in fact, the usual one, is that of watching birds while taking their natural food in the free state. Now and then a fact may be learned in this way which would escape detection in any other,—such as the perforation of the cocoons of Cecropia by the downy woodpecker reported by F. M. Webster,*—but usually this method is of wholly secondary usefulness. The difficulty is very great of telling with certainty, in the great majority of cases, just what a bird is eating, even if one watches it with a glass. The notion of the food resulting must be distorted, as the species will be seen much more frequently and clearly in some of its haunts than in others. It is impossible by the use of this method, even to *guess* intelligently at the *ratios* of the different elements of the food—a matter of the first importance to an understanding of the subject. It yields very few facts for the time expended, and these, in nearly every instance, could have been learned in much less time, with far greater certainty, and in far greater detail, by the following method. Finally, it affords no means of reviewing observations, but the impressions received from the hasty and imperfect glance of a moment must either be rejected wholly or must stand as verified observations.

By the third method, however, that of examining the contents of the stomachs after death, each bird usually affords a large number of objects which can be studied critically, and in detail, and can be indefinitely preserved for reference. These objects give a nearly or quite complete and impartial record of the food for some hours past,—those elements taken in a thicket or a tree-top being as evident as those taken on open ground. They are usually identifiable by the skilled student. Even very minute fragments will tell as much as the out-of-door observer can learn under the most favorable circumstances. In the great majority of cases it is possible so far to fix the kinds of food as to bring every element clearly into one of the three classes, beneficial, injurious or neutral. And here opportunity is afforded for careful and trustworthy esti-

*In an unpublished paper read at the meeting of the Illinois State Nat. Hist. Soc., at Bloomington, Feb., 1880.

mates of the ratios each element bears to the other, so that the average significance of the food can be discovered. Practically, this is indispensable. Whatever method fails of this, while its results may be interesting, and may have a certain general value, can never afford a basis for anything better than indefinite opinion. It can never settle the case for or against the birds.

This method, while by far the best of the three, has its slight disadvantages. Some things eaten by birds leave no appreciable trace in the stomach. For example, it is difficult, by this method, to determine with certainty those birds which greatly injure grapes by breaking the skin of the fruit and sipping the juice. This difficulty applies only to liquid food. Other errors may arise from the shorter or longer periods for which different kinds of food will last in the stomach; but of this we have no proof. I have depended almost wholly on this third method of investigation, because it is evidently the most profitable and reliable, and because the method of cursory observation having been resorted to heretofore, most of the recorded facts are due to it. So far as one method could correct the deficiencies of the other, it was desirable that this more tedious and laborious but more fruitful one should be given greater prominence.

The stomachs of birds shot at all times of the year and in all parts of the state, have been preserved in alcohol, each labeled with name, date and locality. The contents of these stomachs were afterwards transferred, for permanent preservation, to separate vials, bearing copies of the original labels. They were then examined, bit by bit, with the microscope, with whatever powers were necessary to the fullest possible understanding of each fragment. It has been no uncommon thing to spend half a day over a single bird. Full notes of the materials found in each stomach were made on separate slips, and after this careful examination an estimate was made and recorded of the ratios of the different elements to the whole mass of the food of each individual. Objects which I was not able to identify have usually been sent to some more experienced specialist, except where determination was evidently impossible.*

These memoranda were afterwards classified and the data arranged in tabular form, so as to give a complete recapitulation and summary of the food of each species for each month. The tables thus constructed have furnished the basis for the discussion of the food of the species; and a similar tabular summary of the food of the family has been used in a similar way. Thus every fact observed appears in the final conclusion, and receives, there, its due weight.

Family TURDIDÆ. The Thrushes. †

This family consists, in Illinois, of nine species of birds; the robin, the catbird, the brown thrush, the wood thrush, the hermit thrush, Swainson's thrush, the Alice thrush, the mocking-bird and Wilson's thrush or the Veery. The first four of these stay with us in this latitude during the summer ; the others emigrate beyond our borders, except the mocking-bird, and that only reaches the southern third of the state in any considerable numbers. I have now carefully studied the food of three hundred and fifteen specimens of this family, shot in various parts of Illinois, and in all months from February to October.

Turdus migratorius, L. The Robin.

This bird, as familiar to every one as the domestic cat, is the most abundant of the thrushes, and plays so large a part in the economy of the farm and garden as to make the question of its food one of unusual importance. The species ranges from the Atlantic to the Pacific and from the Mexican plateau to the Arctic circle, at home in all the latitudes and longitudes of this vast and varied country. I cannot, of course, attempt to determine, at present, the food of the species throughout this immense area,

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*For assistance of this sort, I am indebted above all others to Prof. C. V. Riley, Chief of the U. S. Entomological Commission at Washington, D. C. I have called upon him especially foi the identification of larvæ, and my drafts have never been dishonored.

†The general reader is referred to the "recapitulations" and the discussions of the "economic relations" of each species for the most important facts of these papers.

but shall endeavor to show only what it eats under ordinary circumstances within the limits of Illinois. The species is not strictly migratory, but is reported as wintering, sometimes in considerable numbers, as far north as the White Mountains, in New Hampshire. It occurs but very rarely in winter in central or northern Illinois, as there is at that season not sufficient food to tempt it to brave our prairie winds. On the other hand, it is comparatively rare in southern Illinois in summer, but usually abundant there in autumn and winter, so that as far as this state is concerned, it is practically a migrant within our limits. In the latitude of Bloomington its advent depends on the forwardness of the season, but it usually appears not far from the first of March, and the last of the species are gone by October 15th or November 1st.

The nesting habit of this species is so varied that no special provision need be made by those wishing to encourage its multiplication. The lower branches of orchard trees are probably its favorite situation, but it selects the most various places and uses little art or caution in the concealment of its nest.

February.

The robin appeared at Bloomington, this year, in considerable numbers, about the middle of February, the spring being an unusually early and open one.

Eleven specimens were shot at Normal, on the 27th and 28th, and their stomachs carefully searched for food. We first note that ninety-nine per cent. of the food of these birds was insects, the remaining one per cent. being spiders. About fourteen per cent. of the food of these early birds consisted of caterpillars, all of them eaten by three birds, while seventy-six per cent. taken by every bird, was the larva of a slow, torpid fly, abundant in early summer, closely related to the Tipulids or crane-flies (*Bibio albipennis*, Say). Prof. J. W. P. Jenks, now of Brown University, found this same larva to constitute about nine-tenths of the food of the robins examined by him in Massachusetts, in February and March, 1858,—a fact which indicates a remarkable fixity of food habits, unaffected by twenty years of time and a distance of a thousand miles.

The caterpillars were partly cutworms, about one-third of them being recognized as the "speckled cutworm" (*Mamestra subjuncta*, G. & R.), a species supposed to be injurious to cabbages.* Coleoptera occurred in the stomachs of these birds only in small numbers, comprising about four per cent. of the food. Half of these were Carabidæ, eaten by six of the eleven birds, a fourth were scavenger beetles (*Aphodius inquinatus*) and a fourth were larvæ of Lampyridæ, including one of Chauliognathus. A few fragments of curculios were also found.

Grasshoppers were present in about the same quantity as beetles, but only two birds had eaten them. One had taken *Tragocephala infuscata* and another a Tettigidea.

The Hemiptera (one per cent.) were chiefly soldier-bugs (Pentatomidæ), eaten by five of the birds. The spiders had been taken by two birds, and one had eaten a small thousand-legs (Iulus).

The striking feature of the month is the great predominance of the larva of Bibio in the food, a fact which will seem of small or great importance according to our views of the habits of this larva. By Dr. Fitch, former state entomologist of New York, as quoted by Prof Jenks,† it was believed to be especially injurious to grass lands, and the robin was therefore credited with an indispensable service to the farmer. Dr. Fitch gave no actual observations, however, and his opinion was apparently speculative. Mr. Walsh‡ and Prof. Riley have since reported that the larva feeds only on decaying vegetation and is therefore harmless, if not indeed useful. Prof. Riley has, in fact, reared it in rotten leaves where no living vegetation was accessible. Finding the robin feeding on it so excessively in spring, I took some specimens from among the roots of grass and weeds in a raspberry garden and others from the stomach of a robin, examined the contents of the intestine with a microscope, and mounted the material

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*Prof. Riley, by whom my specimens were determined, says that he reared the larva on cabbage, which it ate voraciously.

†Journal of the Massachusetts Horticultural Society, Boston, March, 1859, p. 152.

‡The Practical Entomologist, Vol. 2, No. 4, p. 45, January, 1867.

for permanent preservation, These larvæ were filled with vegetation, some of which was recognized as the leaves and rootlets of the grass-like weeds of the vicinity, while the remainder evidently consisted of the leaves of net-veined plants, probably trees, by which the ground was overshadowed. The frequency with which these tissues were found penetrated by fungi showed that this vegetation was in a decaying condition. I next looked through my notes of the contents of the stomachs of meadow-larks shot at the very time when the robins were stuffing themselves with this Bibio larva, and found that the meadow-larks had not eaten so much as one. As they search the ground more closely than the robin, relying almost as fully on insect food, this seemed good evidence that the larva occurs here chiefly in situations frequented by the robin and not by the meadow-lark,—that is, in gardens, groves and the like. It was only in such situations that I was able to find it myself. There is, therefore, no present evidence that this larva is now injurious even in the slightest degree, and the robin is not entitled to any very positive credit for its destruction. There is some probability, however, that if the insect were allowed to increase indefinitely, it would become injurious to living vegetation; and if so, the high rate of its multiplication would make it a seriously destructive pest. The immense numbers annually destroyed by the robin may be inferred from the fact that I have counted as many as one hundred and seventy-five from the stomach of a single bird; and as fully half of the food of the robin for a month consists only of this insect, fifty larvæ a day for each robin, or one thousand five hundred for the month, will be a very moderate estimate.

About five per cent. of the food of February consisted of beneficial insects.

March.

Nine birds were shot on four different days of March, between the 9th and 31st, six of them in McLean county, and three at Galena. Four of these had eaten Bibio larvæ again, which amounted to thirty-seven per cent. of the food of the month. Four birds are to be credited with the thirty per cent. of caterpillars destroyed. About two-thirds of these were cutworms, among which *Agrotis messoria*,* was recognized. A few were the larvæ of Arctiidæ, probably Callimorpha. Eighteen per cent. of the food, eaten by seven of the birds, was made up of Coleoptera, two-thirds of which were scavenger beetles (*Aphodius fimetarius* and *A. inquinatus*). Carabidæ and their larvæ made but two per cent. of the food. Harpalus was the only genus distinguished. A few Histeridæ, a few wireworms (larval Elateridæ), a soldier-beetle (*Telephorus bilineatus*), and traces of long-snouted curculios† were the remaining beetles. Hemiptera were found in somewhat larger number and variety than in the preceding month. Among these were the raptatorial species, *Coriscus ferus*, and also *Phytocorus lineolarus*, *Cœnus delius* and *Euschistus servus*. The soldier-bugs (Pentatomidæ) made about two-thirds of the three per cent. of Hemiptera taken in this month. Grasshoppers were present in about the same amount as before, and the same species appeared in the food. A few spiders and thousand-legs and berries of sumach (*Rhus glabra*) complete the list. The large percentages of cutworms, Bibio larvæ and dung-beetles are thus seen to be the principal features of the food of these birds. Excluding the Bibionidæ, about thirty-seven per cent. of the food was composed of injurious insects and six per cent. of beneficial species.

April.

The robin is represented in my notes of this month by seventeen birds shot at Normal, Warsaw, Elizabeth and Hanover (Jo Daviess county), Waukegan and Evanston, at various dates between the 2d and 27th. The high insect averages are maintained. Caterpillars are nearly as abun-

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*All the cutworms but one mentioned in this paper were determined by Prof. Riley.

†I have used throughout this paper the somewhat artificial divisions of Longirostres and Brevirostres as applied to the Rhyncophora, because nearly all the especially injurious species belong to the former section. In fact, I have not hesitated to use an obsolete classification wherever the groups thus formed correspond better to the differences of food habit or of economic value than those made by the highest modern authorities.

dant as before and make about a fourth of the food. Arctiidæ and Phalænidæ (measuring-worms) appear in some quantity, but of unrecognized species. The larvæ of Bibio fall to eight per cent. and do not again appear in the food during the year.

A strong upward jump in the ratios of Coleoptera, which rise in this month to forty-two per cent., is doubtless due to the greater activity of beetles during this season of their amours. The effect is clearly seen by running along the line of averages for Coleoptera from February to October, viz.: 4, 18, 42, 44, 15, 9, 7, 5, 3. The upward swell which commences in March and dies away in June, corresponds to the time when the procreative impulse overcomes the usual discretion of these insects, and draws them out more freely into the open air. It is in this month that the bird makes its principal attack on the predaceous beetles, which are represented by an average of seventeen per cent., eaten by eleven of the birds. Thirteen heads of *Harpalus herbivagus*, for example, were taken from the stomach of a single robin. Other species of Harpalus, *Brachylobus lithophilus*, *Anisodactylus baltimorensis*, *Geopinus incrassatus*, Pterostichus and Amara were observed. Scarabæidæ also occur in unusual abundance at this time (fifteen per cent.), as might be anticipated by one who recalls the numbers in which they are now seen flying in the air. May-beetles (Lachnosterna) make about half of these, and Aphodii the other half. A single bird had happened upon an interesting store of water-beetles (Hydrophilidæ) which included a specimen of *Hydrocharis obtusatus*, several of *Philhydrus cinctus*, and a number of Helophori unknown to me. Rhyncophora amount to about three per cent. of the food. Only Centrinus and *Graphorhinus vadosus* were recognized. Minor items were the traces noticed of Elateridæ, Lampyridæ and Chrysomelidæ.

Hemiptera stand at about the ordinary average (three per cent.), as usual chiefly Pentatomidæ. *Coriscus ferus*, some indeterminable Reduvid, *Podisus modestus* and *Hymenarcys nervosa* were the principal forms. The Orthoptera (five per cent.) call for no especial remark; neither do the Arachnida (one per cent.). One bird had eaten a predaceous thousand-legs (Geophilus), and two had eaten earthworms (five per cent.). The infrequent occurrence of the last in the stomachs of robins surprised me. It is probably due partly to the greater digestibility of these soft worms as compared with the chitinized skins of insect larvæ, and partly to the fact that the greater part of those taken by the robin are fed to the young. A few sumach berries eaten by the woodland robins shot in northern Illinois complete the dietary of the month.

The April food of the robin is, therefore, especially noticeable for the greatly diminishing number of Bibio larvæ and the excessive number of beetles eaten, especially of the Carabidæ and Scarabædiæ.

May.

Fourteen birds were studied for this month, all but two of them from various parts of northern Illinois. The record of May is substantially a duplicate of the April list, except in a few particulars. The Bibio larvæ are replaced by seven per cent. of adult crane-flies (Tipulidæ) and the Carabidæ drop to four per cent., the balance being almost exactly replaced by the scavenger beetles and leaf-chafers added. Chlænius and *Agonoderus partiarius* are among the captures of these birds. Lachnosterna rises to its highest point in May, and is represented by seventeen per cent. of the food. Wireworms (Elateridæ) are likewise unusually abundant, for some unexplained reason, amounting to eight per cent. A single robin had eaten a single potato beetle (*Chrysomela* 10-*lineata*), and one had taken a specimen of *Prometopia* 6-*maculata*. *Cœnus delius* appears among the Pentatomidæ and Polydesmus among the thousand-legs; and sumach berries again occur.

June.

With June the robin revolutionizes his commissariat. The insect ratios, which have averaged ninety-five per cent. during the preceding months, now drop to forty-two, and remain at or below this point for the rest of the year; and this lack is compensated by the appearance of fifty-five per cent. of cherries and raspberries. The loss falls chiefly upon the Diptera and Coleoptera, the former dropping from eleven per cent. to less than one, and the latter from forty-four per cent. to fifteen. Among the families of Coleoptera we see from the table that it is the Scarabæidæ which benefit chiefly by this diversion of the robin's activities; for, while the other families remain about as before, this family drops from twenty-two per cent. in the preceding month to one in this.

Taking up the details of the food of the thirteen June robins, ranging from the 10th to the 29th, all shot at Normal, we first notice the larger percentage of ants. These have hitherto occurred in but trifling numbers,—(three per cent. in the preceding month),—but are now more than twice as common in the food. This fact is doubtless due to the same cause as the still greater relative abundance of the ants in June in the food of the bluebird,—to the abundance of the winged perfect forms of some species at this time. Caterpillars stand at seventeen per cent., seven per cent. being cutworms. Carabidæ form six per cent. of the food. Among the adults were *Callida punctata*, *Cratacanthus dubius*, Agonoderus and Anisodactylus. Wireworms were again numerous, four per cent being eaten by seven of the birds. Forty-seven per cent. of the food of these birds was cherries and eight per cent. raspberries.

July.

The fourteen July birds were evidently reveling in the fruit garden, raspberries, blackberries, and currants forming seventy-nine per cent. of the food.*

On the other hand, but twenty per cent. of the food was insects and one per cent. was spiders. The caterpillars furnish only four parts of the food, and beetles but nine parts, of which two-thirds were Carabidæ. Evarthrus, Pterostichus and Amara were noticed among these. Scarabæidæ, Elateridæ, and Rhyncophora each one per cent., a mere trace of Hemiptera, four per cent. of Orthoptera (chiefly crickets), eaten by two of the birds, and one per

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*I have not ordinarily attempted to distinguish raspberries from blackberries in the stomachs of birds, but have set down either one or the other, according to the advancement of the season.

cent. each of Arachnida and Myriapoda are the remaining trivial details.

August.

This month is represented by twenty birds, all shot at Normal,* at repeated intervals from the fourth to the thirtieth. With the disappearance of blackberries, the food of this bird returns substantially to the status of June. Insects increase again to forty-three per cent. and fruits fall to fifty-six. Ants remain at the usual point of insignificance, caterpillars rise again to seventeen per cent., about two-thirds of them Noctuidæ. Coleoptera figure at seven per cent., only two per cent. being Carabidæ, Rhyncophora rise to four per cent., eaten by nine of the birds; and, except a stray Nepa picked up by one robin, Hemiptera appear in trifling quantity. Crickets and grasshoppers are more abundant, amounting to ten per cent. of the food.

The cherries made forty-four parts of the food of the month, eaten by fourteen of the birds, *but two-thirds of these cherries were wild.* Tame grapes make three per cent. of the food, berries of the mountain-ash about four per cent., and blackberries from the woods not far from five per cent.

September.

Twelve birds, all but one shot at Normal September 25th, and that one at Aurora on the 13th, show no more remarkable peculiarity than the substitution of ants for most of the caterpillars, the former composing now fifteen per cent. of the food, and the latter but five. The ants were largely winged, but of different species from those taken most freely in June.† The Carabidæ of this month were chiefly larvæ. Among the Hemiptera (three per cent.) were found *Mormidea lugens* and *Cœnus delius*. No

*The general cessation of taxidermist's field work in midsummer has prevented the supply of any material for this month and the preceding, except that obtained by ourselves in McLean county.

†Examining the tables of food of the bluebird, brown thrush and robin, I find throughout a curious inverse relation between the ratios of ants and caterpillars, the latter falling away in June to about the same degree that ants increase during the time of their most conspicuous activity. I cannot even guess why ants should thus replace caterpillars in the food.

trace of spiders or myriapods was found, and only two per cent. of grasshoppers. The fruits stand at seventy per cent., fifty-two per cent. being grapes and the remainder berries of the mountain-ash and moonseed (Menispermum).

October and December.

The robin commences to withdraw to the south in October, and his operations in central Illinois have little interest during this month. At Normal the species became rare earlier than usual this year, and but three specimens were secured. These were feeding largely on wild grapes (fifty-three per cent.) and ants (thirty-five per cent.). Six per cent. of the food was caterpillars and two per cent. wireworms (Elateridæ). I have seen the bird eating apples in all the autumn months, but have never found the remains of this fruit in the stomach, and doubt if any especial harm is done in this way.

A single bird shot at Cairo in December, piping loudly from a tree-top for company, the only one of the entire family seen during a week's winter shooting in southern Illinois, had evidently been feeding on the berries of the mistletoe. By the inhabitants of that region, troops of robins which commonly winter there were said to have gone south in November, a fact attributed by them to the failure of the wild grapes in the woods that year.

Recapitulation.

The food of the robin, as indicated by the stomachs of one hundred and fourteen specimens, consists almost entirely of insects from February to May inclusive, but from that time forward these make but little over a third of its food, the remainder (sixty-four per cent.) being composed of fruits, tame and wild, in varying proportions, according to the local situation and surroundings. Insects make almost precisely two-thirds of the food of the year, taken as a whole.

In early spring the bird depends chiefly for food upon the larvæ of a single species of fly (*Bibio albipennis*, Say), which it picks from among the leaves and roots of grass and weeds in gardens, and similar situations. In February this made three-fourths of the food of eleven specimens, and in March more than a third of the food of nine. While this larva is not at present injurious, but feeds ordinarily on decaying vegetation, it might possibly do injury to meadows and pastures if allowed to multiply without restraint.

But few ants are eaten by this bird until late in the fall, when the swarming of the sexual forms of some of the species seems to attract its appetite, in the relative dearth of other insects.

Caterpillars make up, in March, April and May, fully a fourth of its food, about half of these being cutworms and other similar forms. Later, these are largely given up for fruit, and in the latter half of the season make only about one-tenth of the food. The average of caterpillars for the year is seventeen per cent.

Beetles, commencing at four per cent. in February, when but few specimens have yet been aroused from their cold winter's sleep, rise to forty-four per cent. in April and May, when their procreative energies are most active and urge them out into the air in swarms. With the appearance of the small fruits, beetles, also, are neglected by the robin, and the average for the last four months of the season falls away to six per cent., eighteen being that for the year.

This discrimination affects chiefly the scavenger beetles and the "June beetles," the other families maintaining about their original numbers throughout, with only an upward wave in April. The predaceous beetles average six per cent. of the food of the year, the leaf-chafers three per cent., the wireworms two per cent., and the snout-beetles one per cent.

The robin's depredations upon the true bugs (Hemiptera) are but trivial, amounting only to three per cent. of the food, but nearly all of these belong to species regarded more or less positively as beneficial.

The ratio of grasshoppers and crickets (four per cent.) seems trivial at first sight. We note, however, that these were eaten by twenty-six of the birds, and that, consequently, at least twenty-six of the insects must have been destroyed. Remembering that these figures are based upon a single day's food, or even less, for each bird, we see that these robins were eating at an average rate of at least twenty-six grasshoppers or crickets a day, for seven months, giving us a minimum total of 5,500 Orthoptera for the year.

Only one per cent. of the food was spiders. Thousand-legs were eaten by eight of the birds, and by these in merely trivial quantity.

Coming now to the fruits, we find that tame cherries, blackberries, raspberries, currants and grapes, excluding wild fruit of all descriptions, make about one-fourth of the food of the species for the year, the wild fruits making another tenth. In the absence of the latter, the robins would doubtless attack the garden fruits more vigorously.*

Concerning these general statements, the all-important question is, of course, the sufficiency of their basis.

Granting that the observations have been exactly made and correctly generalized, how far may the conclusions reached be expected to hold good in the future? These conclusions actually rest upon the food of a hundred and fourteen birds for probably about half a day each. Can we safely reason from these to the food of the thousands and hundreds of thousands of robins of the state, day after day, the whole season through?

In a paper published last winter in the Transactions of the Illinois Horticultural Society, I made the following reply to substantially the same question:—

"If the same species will eat substantially the same food, year after year, in the same situation, then, of course, a good deal may properly be inferred from comparatively few data; but if the food varies widely, either arbitrarily or under slight changes of condition, then we can infer but little. Upon this fundamental question I have two suggestions to make.

"First, if several species allied in structure, occupying the same territory at the same time, living side by side,

*No man should needlessly sacrifice a wild cherry-tree or a fruiting vine or shrub of any kind. Ordinary common sense would teach the preservation of as much of the worthless natural food of frugivorous birds as possible, as a diversion from the cultivated fruits of the orchard and garden.

with the same sources of food supply open to them, are found, on the examination of a limited number of stomachs, to present several characteristic differences of food, so that the investigator can point out definite peculiarities of the food of each species, and finds these peculiarities reasonably constant, year after year, then we may say unquestionably, without going farther, that there is a fixity of food-habits in this group of birds which will allow us to reason from the data observed.

"Second, if there are any other habits of the species in which there does not seem to be any greater reason for invariableness than in those relating to the food, which are nevertheless found to be substantially unvarying, then we may, with considerable force, argue the probability of a like unvarying character in the habits of alimentation.

"Respecting the first of these tests, you will see, when I sum up the food of the family now under consideration and bring the data respecting the various species into comparison with each other, that I have made out certain very well-marked specific differences of food, even among those eating at the same table; that the different species of this group, while agreeing in many particulars of food as they do in structure, present also certain peculiarities, so marked that I can usually determine the species by the contents of three or four stomachs.

"For the second test we may properly use the nesting habit. There seems to be no more cogent reason why one species should select from the same storehouse different materials for its nest from those used by another closely allied species of nearly the same size and similar general habits, and building in the same locality, than why each should use a similar fixed discrimination in selecting its food. Yet no expert, scarcely a schoolboy even, will hesitate a moment between the nest of a robin and that of a catbird; and the descriptions of the two given in the books are so different as to enable any novice to distinguish between them at a glance. In fact, a friend mentions, as I write, two birds whose nests are much more easily distinguished than the birds themselves."

I have now to add what we may regard as a decisive crucial test of the conclusion implied above. In the paper quoted from, I gave the details and a summary of the food of forty-one robins in a table similar to those presented in this paper, and a comparison of the averages of that table with those of the table on pages 112, 113, 114, 115, may be easily made. While any serious differences in the averages of these two tables would not necessarily condemn the later one, but, at the worst, would leave its sufficiency in doubt, a substantial agreement of the two would be conclusive proof of the correctness of both. It is incredible that the averages of a hundred and fourteen specimens should agree essentially with those of forty-one, unless both were framed upon identical principles and were sufficiently true to the facts for all practical purposes. I will, therefore, place the principal averages of these tables side by side, premising that the later table not only includes nearly three times as many specimens as the earlier, but covers two months' more time.

The figures for the first and second tables, taken alternately, are as follows:—Insects, seventy per cent. and sixty-five per cent.; caterpillars, eighteen per cent. and seventeen per cent.; Diptera, eighteen per cent. and seventeen per cent.; Coleoptera, nineteen per cent. and eighteen per cent.; Carabidæ, seven per cent. and five per cent.; Scarabæidæ, four per cent. and seven per cent.; Lachnosterna, two per cent. and three per cent.; Elateridæ, three per cent. and two per cent.; Rhyncophora, three per cent. and two per cent.; Chrysomelidæ, one per cent. and a trace; Hemiptera, four per cent. and three per cent.; Orthoptera, eight per cent. and four per cent.; Arachnida, a trace and one per cent.; Myriapoda, two per cent. and a trace; garden fruits, twenty-eight per cent. and twenty-nine per cent.

As I did not discriminate, in the former table, between tame and wild edible fruits, I have included the latter in both, and excluded the inedible fruits. I believe that the agreement in these figures, taken into account the earlier and later months covered by the second table, is quite remarkable, and can be explained only on the supposition that the fuller table presents a reasonably accurate summary of the food of the robin as a species in at least the northern half of the state, and under the ordinary conditions of the last five or six years. Of course, I had no idea how these averages were coming out until my notes were finished and the ratios were calculated for the whole.

Economic Relations.

We come now to the intricate, delicate and difficult question of the economic relations of this species,—a question rendered less important by the general considerations urged elsewhere, but, nevertheless, deserving careful attention. While it is true that every insectivorous bird must be respected, whatever its other habits, at least until we clearly understand its function in the general order and are certain that its removal will do no harm which we can not remedy or endure better than we can support its injuries, yet an idea of the relative importance of edible fruits and insects of both the beneficial and injurious classes in the diet of the bird is necessary as a step to this clear and complete understanding of the matter.

Glancing at the bottom of the table of the food of the species, on page 115, the reader will see three lines of figures running across the page, showing for each month the percentages of beneficial, injurious and neutral species of insects and fruits eaten by these birds. The figures at the right give similar percentages for all the birds for the entire year. Following the upper line, we note the small percentages of injury done in the early spring, the marked increase of injury in April, due to the excessive destruction of predaceous beetles, and the heavy percentages of the fruiting months. The general average of beneficial elements destroyed for the year is thirty-six per cent. On the second line we notice an inverse variation. Commencing with a ratio of ninety-four per cent. of injurious elements eaten in February (if we include the larva of Bibio in these), the record runs down to seven per cent. in September, the general average for the year being forty-three per cent.

This comparison, however, is merely a quantitative one. Injurious or beneficial elements are balanced against each other according to their bulk and not their quality. A quart of caterpillars counts as the equivalent of a quart of blackberries, and, on the other hand, as the equivalent, also, of a quart of predaceous beetles. It is evident, therefore, that we cannot get at any close estimate of the economic values of this species in this indiscriminate way.

A nearer approximation to the truth may be made by critically comparing the general averages for the year found in the vertical column at the right of the table. Here we have the following totals of injurious and beneficial species:—Of the first, caterpillars, seventeen parts (including eight parts cutworms); Bibio larvæ, fifteen parts; leaf-chafers, three parts; wireworms, two parts; snout-beetles, two parts; crickets and grasshoppers, four parts. Of the second, predaceous beetles, six parts; predaceous bugs, three parts; garden fruits, twenty-four parts. Now, the opinions of entomologists would probably be found to differ somewhat widely on the question of the relative values of these various elements, and each must form his own opinion from the data given.* My own judgment is that, taking into consideration only the immediate present effect of the robin upon the fruits and insects of the state, ignoring for the moment the important secondary disturbances likely to arise if the number of the species were greatly lessened, and balancing these elements carefully against each other (applying to them, in fact, the operation of cancellation in arithmetic), we can reduce the question finally to about this form:—Will the destruction of seventeen quarts of average caterpillars, including at least eight quarts of cutworms, pay for twenty-four quarts of cherries, blackberries, currants and grapes?

To this question I, for my own part, can only reply that I do not believe that the horticulturalist can sell his small fruits anywhere in the ordinary markets of the world at so high a price as to the robin, provided that he uses proper diligence that the little huckster doesn't overreach him in the bargain. In other words, while the bird is far too

*Concerning the value of predaceous beetles, the reader is especially requested to examine the papers on that subject in the present bulletin. It is probable that their services have been greatly overestimated.

valuable to exterminate, at least until we are sure we can replace him by some cheaper assistant, yet he is not so precious that we need hesitate to protect our fruits from outrageous injury. Indeed, it seems likely that the ordinary destruction of robins by gardeners does not more than compensate for the destruction of birds of prey in the interests of the poultry yard,—removing that excess of robins which, in the more natural order, would fall victims to the hawks and owls.

TABLE OF THE FOOD OF THE ROBIN. (*Turdus migratorius* L.)

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food
Number of specimens	...	11	9	17	14	13	14	20	12	3	...	1	114	
KINDS OF FOOD.	Number of specimens, and ratios in which each element of food was found.													
I. MOLLUSKS	...	...	...	1 .01	1 †	...	...	...	...	...	...	...	2	....
II. INSECTS	...	11 .99	9 .97	17 .91	14 .94	13 .42	13 .20	18 .43	9 .30	3 .44	...	...	107	.65
1. *Hymenoptera*	...	...	1 †	5 .02	7 .03	6 .07	3 .01	10 .03	7 .15	2 .35	...	...	41	.04
Apidæ	...	...	...	1 †	...	...	1 †	...	...	...	...	...	2	....
Formicidæ	...	...	...	4 .02	7 .03	6 .07	3 .01	7 .02	7 .15	2 .35	...	...	36	.04
Ichneumonidæ	...	...	...	...	...	...	...	1 †	...	...	...	...	1	....
Chalcididæ	...	...	1 †	...	...	...	...	...	...	...	...	...	1	....
2. *Lepidoptera* (larvæ)	...	3 .14	4 .30	12 .24	11 .23	8 .17	3 .04	11 .17	2 .05	2 .06	...	...	56	.17
Arctiidæ	...	...	1 .01	3 .02	...	...	...	...	...	...	...	...	4	....
Noctuidæ	...	1 .05	3 .19	1 .04	6 .15	4 .07	...	7 .12	1 .01	...	...	...	23	.08
Phalænidæ	...	...	...	1 .05	...	...	...	...	...	...	...	...	1	....
3. *Diptera*	...	11 .76	4 .38	6 .12	4 .11	1 †	1 .01	1 †	...	...	...	...	28	.17
Tipulidæ	...	...	...	...	2 .07	...	...	...	...	...	...	...	2	.01
Bibionidæ	...	11 .76	4 .37	3 .08	...	...	...	...	...	...	...	...	18	.15

TABLE OF THE FOOD OF THE ROBIN. (*Turdus migratorius*, L.)—Continued.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens......	...	11	9	17	14	13	14	20	12	3	...	1	114	
KINDS OF FOOD.	Number of specimens, and ratio in which each element of food was found.													
4. *Coleoptera*............	...	8 .04	7 .18	16 .42	11 .44	11 .15	8 .09	14 .07	3 .05	3 .03	...	...	81	.18
Carabidæ	...	6 .02	5 .02	11 .17	6 .04	6 .06	3 .06	7 .02	2 .03	1 .01	...	...	47	.05
Harpalidæ	...	4 .01	4 .02	11 .16	6 .04	5 .01	2 .06	5 .02	2 .03	1 .01	...	...	40	.05
Larvæ	...	...	1 .01	...	...	1 †	2 .01	...	1 .02	...	...	...	5	....
Dytiscidæ...............	...	...	...	...	...	...	...	1 †	...	...	...	...	1	....
Hydrophilidæ	...	...	...	1 .01	...	...	...	...	...	...	...	...	1	....
Staphylinidæ	...	...	...	...	1 .01	...	...	...	...	...	...	...	1	....
Histeridæ	...	...	1 .01	...	8 .05	1 †	...	1 †	...	...	...	...	11	.01
Nitidulidæ	...	...	...	...	...	...	...	1 †	1 †	...	...	...	2	....
Scarabæidæ..............	...	3 .01	4 .12	13 .15	12 .22	4 .01	3 .01	1 .01	...	...	...	...	40	.07
Lachnosterna..........	...	...	...	2 .07	6 .17	1 †	1 †	...	...	...	...	...	10	.03
Elateridæ...............	...	...	2 .01	2 †	4 .08	7 .04	2 .01	1 †	1 †	1 .02	...	...	20	.02
Lampyridæ..............	...	2 .01	1 .01	1 †	...	1 .02	...	...	...	...	...	..	5	....
Rhyncophora............	...	2 †	2 .01	5 .03	7 .02	4 .01	1 .01	9 .04	...	...	...	...	30	.02
Brevirostres	...	...	...	3 .02	4 .01	...	...	...	...	...	...	...	7	....
Longirostres..........	...	1 †	2 .01	3 .01	4 .01	...	...	2 .02	...	...	...	...	12	....
Chrysomelidæ............	...	...	...	1 †	2 .01	2 .01	...	1 †	...	1 †	...	...	7	....
Doryphora............	...	...	...	...	1 .01	...	...	...	...	...	...	...	1	....
5. *Hemiptera*............	...	5 .01	3 .03	5 .03	6 .05	3 .01	2 †	6 .06	5 .03	...	...	...	35	.03
Nepa....................	...	...	...	...	...	...	...	1 .05	...	...	...	...	1	....
Coriscus................	...	...	1 †	1 †	1 †	...	...	1 †	...	...	...	...	4	....
Reduviidæ	...	...	...	1 †	1 †	1 †	1 †	2 †	....	...	...	...	6	....
Phytocoreidæ............	...	...	1 †	...	...	...	...	1 †	...	...	...	...	2	....

TABLE OF THE FOOD OF THE ROBIN. (*Turdus migratorius*, L.)—Continued.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens......	...	11	9	17	14	13	14	20	12	3	...	1	114	
KINDS OF FOOD.	Number of specimens, and ratio in which each element of food was found.													
Lygæidæ (Blissus).......	...	...	...	...	...	...	...	...	1 †	...	...	...	1	....
Coreidæ	...	1 †	1 †	...	...	...	...	...	...	...	...	...	2	....
Pentatomidæ	...	5 .01	3 .02	5 .03	4 .04	1 †	1 †	3 †	4 .02	...	...	...	26	.02
6. *Orthoptera*.	...	2 .04	2 .05	6 .05	5 .04	1 .01	2 .04	6 .10	2 .02	...	...	...	26	.04
Gryllidæ	...	...	...	1 .01	...	...	1 .03	3 .06	...	...	...	...	5	.01
Acrididæ	...	2 .04	2 .05	3 .03	5 .04	1 .01	2 .01	3 .04	2 .02	...	...	...	20	.03
III. ARACHNIDA...........	...	2 .01	1 .01	3 .01	1 †	...	4 .01	3 .01	...	...	...	...	14	.01
IV. MYRIAPODA...........	...	1 †	3 .01	3 .01	1 .02	...	...	...	...	...	...	...	8	....
Geophilus	...	...	1 †	1 .01	...	...	...	...	...	...	...	...	2	....
Polydesmus	...	...	...	...	1 †	...	...	...	...	...	...	...	1	....
Iulidæ	...	1 †	2 .01	2 †	1 .01	...	...	...	...	...	...	...	6	....
V. EARTHWORMS (*Lumbricus*)	...	...	...	2 .05	...	...	...	...	...	...	...	...	2	....
VI. FRUITS AND SEEDS	...	1 †	2 .01	1 .01	3 .04	13 .58	14 .79	17 .56	11 .70	3 .56	...	1 100	65	.34
Blackberries............	...	...	...	...	...	...	12 .56	...	...	...	...	...	12	.07
Raspberries	...	...	...	...	...	3 .08	1 .05	...	...	...	...	...	4	.02
Cherries................	...	...	...	...	...	10 .47	...	[a]14 .44	...	...	...	...	24	.11
Currants	...	...	...	...	...	...	6 .17	...	...	...	...	...	6	.02
Grapes	...	...	...	...	...	...	...	1 .03	7 .52	[b]2 .53	...	...	10	.07
Mistletoe (Phorodendron)	...	...	...	...	...	...	...	...	...	...	...	1 100	1	....
Mountain-ash............	...	...	...	...	...	...	...	1 .04	1 .08	...	...	...	2	.01
Sumach (Rhus)..........	...	...	2 .01	1 .01	2 .04	...	...	...	...	...	...	...	5	.01
Hackberry (Celtis).......	...	...	...	...	...	...	...	1 .05	...	...	...	...	1	....

[a] 28 per cent. wild. [b] All wild.

TABLE OF THE FOOD OF THE ROBIN. (*Turdus migratorius*, L.)—Concluded.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens	...	11	9	17	14	13	14	20	12	3	...	1	114	
KINDS OF FOOD.	Number of specimens, and ratio in which each element of food was found.													
Moonseed (Menispermum)	...	...	...	...	...	...	...	...	2 .04	...	...	...	2	....
Polygonum	...	...	1 †	...	...	...	...	...	...	...	...	...	1	....
Grass	...	1 †	...	...	1 †	1 .02	...	...	...	...	...	...	3	....
Corn	...	...	...	...	...	1 .01	...	...	...	...	...	...	1	....
	Percentages for each month													Ratios.
Beneficial species	...	05	06	21	09	°64	°85	°50	°57	...	...	...	...	36
Injurious species	...	*94	*74	*47	55	24	10	31	07	...	...	...	...	43
Neutral species	...	01	20	‡32	‡36	‡12	‡05	‡19	‡36	...	...	...	...	21

*Includes Bibio. ‡Includes ants. ° Includes fruits.

[NOTE.—In the foregoing tables, the integers indicate the number of birds found to eat the element against which they are placed, and the decimals express the ratio of this element to the whole food of the month. October and December were omitted in computing the general averages for the year, on account of the small number of birds examined for those months.]

MIMUS CAROLINENSIS, L. THE CATBIRD.

This bird, scarcely less abundant than the robin, arrives later and makes a shorter stay, coming late in April or early in May, and disappearing from this latitude usually in September. It also occupies a larger territory in the state in midsummer than the robin, being not at all rare in extreme southern Illinois in July and August. I do not know that it ever winters northward. Its habits and favorite haunts are so similar to those of the robin that one might not unreasonably anticipate that, respecting their food, both could be considered as one species; but we shall see proof that there are specific food characteristics to separate them.

How indefinite and uncertain is the present knowelge of the food of this especially notorious species, may be seen by comparing my notes with the statement made in the recent and elaborate work of Baird, Brewer and Ridgway.

"The food of the catbird is almost exclusively the larvæ of the larger insects. For these it searches both among the bushes and the fallen leaves, as well as the furrows of newly-plowed fields and cultivated gardens. The benefit it thus confers upon the farmer and upon the horticulturist is very great, and can hardly be overestimated."

My observations of this bird cover the five months from May to September, inclusive.

May.

The specimens of this month range from the 1st to the 31st, and from Warsaw and Normal, in central Illinois, to Savanna, McHenry and Waukegan in the northern part of the state. Five of the birds of the month were taken in northern Illinois and seventeen in the central part of the state. All of these birds had eaten insects, which amounted to eighty-three per cent. of the food, the remainder consisting of spiders, three per cent.; thousand-legs (Myriapoda), seven per cent.; and seven per cent. of the dry berries of the sumach (*Rhus glabra*). Among the insects were about equal ratios of ants, crane-flies and beetles, the first composing eighteen per cent. of the food, the second nineteen and the third twenty-three. Caterpillars formed twelve per cent. of the food, and about one-sixth of these were distinctly recognizable as cutworms (Noctuidæ). More than one-third of the beetles were Carabidæ including specimens of Platynus and *Harpalus pennsylvanicus*. Only one per cent. of the food consisted of Scarabæidæ, and five per cent. of snout-beetles (Rhyncophora). Nearly all of the latter belonged to the section Brevirostres, in which are found few of the injurious species of the group. Those recognized were *Epicœrus imbricatus* and *Ithycerus noveboracensis*. Among the one per cent. of plant-beetles (Chrysomelidæ) only *Gastrophysa polygoni* was specifically determinable. Minor items among the Coleoptera are the water-beetles, including *Colymbetes biguttatus* and an undetermined species of Hydrobius. The Hemiptera amounted to only one per cent. of the food, and all of these were Pentatomidæ. The Orthoptera, including a few specimens of the white cricket (Œcanthus) and of the common spring grasshoppers, amounted in all to four per cent. of the food. A single specimen of the young of the walking-stick (*Diapheromera femorata*) had been eaten by one of the birds. Spiders amounted to three per cent. of the food. The Myriapoda included several specimens of Lithobius and three species of Polydesmus, viz.: *P. serratus*, *P. virginiensis* and *P. canadensis*.

It will be seen at once that the striking feature of the food of this bird in May, as compared with that of the robin, is the abundance of ants and crane-flies, a characteristic which we shall find persistent until the opening of the fruit season revolutionizes the food of both species.

June.

The food of June undergoes so complete a change when the small fruits begin to ripen that the record may best be given in two divisions, the first of which agrees closely with that of May, while the second approaches more nearly to that of July. In the first part of the month, ants were eaten by the nineteen birds examined in about the same ratio as in May. Crane-flies appear in the food only in the early days of the month. Among the Coleoptera the principal peculiarity is the greater importance of the May-beetles (Lachnosterna). A few strawberries and cherries were eaten by this bird previous to the fifteenth of the month, but these fruits were not taken in sufficient amount materially to influence the averages. After the seventeenth, however, only one per cent. of the food consisted of ants, and only about three per cent. of caterpillars. The May-beetles disappear almost entirely, and the other insect elements are reduced to equal insignificance, while the same fruits constitute by far the larger part of the food. These include currants and cherries in about equal parts, and about twice as many raspberries as of both the others taken together. Treating the food of the month as a whole, we find that forty-nine per cent. of it consists of insects, three per cent. of spiders and three per cent. of thousand-legs, while forty-five per cent. consists of fruits, twenty-one per cent. being raspberries, twelve per cent. cherries, three per cent. strawberries and eight per cent. currants. The ants of the month amounted to but eleven per cent. and the crane-flies to seven per cent. The Lepidoptera stand at ten per cent. and the Coleoptera at seventeen,—nearly one-third of the latter being Carabidæ. The Hemiptera made about one per cent. of the food and the Orthoptera two per cent. A single bird-louse (Mallophaga) was found in the stomach of one of these birds.

July.

The record of this month rests upon eleven specimens, all from central Illinois, taken from the first to the twenty-third of the month. These indicate most clearly an eminent preference of the species for the small fruits, which composed three-fourths of their food, sixty-four per cent. being blackberries alone. Spiders and myriapods, are found in about the same ratio as in June. The latter are all Iulidæ, a part of them, at least, belonging to the genus Iulus. The only Orthoptera noted were specimens of the large black cricket of the fields (*Gryllus abbreviatus*) eaten by a single bird. The Hemiptera almost disappear, a single Thrips being the only representative of the order. The Coleoptera amounted only to nine per cent. of the food, and more than two-thirds of these were predaceous beetles, eaten by eight birds; among these were noted *Cicindela lecontei*, Pterostichus, Evarthrus, *Cratacanthus dubius*, *Anisodactylus baltimorensis* and Harpalus. Only a single bird had taken caterpillars, which constituted three per cent. of the food of the month. No trace of Diptera was found in the stomachs of these birds, and only four had eaten ants, which made two per cent. of the total food. Insects proper thus amounted to eighteen per cent. of the whole.

It is clear, from the foregoing, that the catbird in midsummer eats only such insects as come in its way while regaling itself on the smaller fruits.

August.

Twelve birds were obtained in this month, the first on the 7th and the last on the 30th, all from McLean and adjoining counties Three of these were young, but as no difference of food was noticed corresponding to age, these are not treated separately.

The food record of August resembles that of June, owing, doubtless, to the diminution of the smaller garden fruits at this time and to the fact that the wild fruits have not yet generally come into bearing. The insect percentages are, therefore, much larger than in July, and it is instructive to notice that this increase is first apparent and most evident in the ratios of ants—an indication of the positive preference of the catbird for this food. Nearly one-half of the forty-six per cent. of insects eaten in this month were ants. A bee, a gall-fly and an ichneumon were noticed among the other Hymenoptera. Forty per cent. of the food was caterpillars, a considerable proportion of which were cutworms. Only six per cent. of the food was Coleoptera, and the only predaceous beetle taken by these birds was one specimen of *Cratacanthus dubius*. Three per cent. of the food was scavenger-beetles, including Geotrupes and *Bolbocerus farctus*. It is in this month that the Meloidæ appear abundantly on goldenrods and other Compositæ, but only a single Epicauta was found in the food of one of these birds. The few plant-beetles noticed included a single *Diabrotica vittata*. Seven per cent. of Hemiptera were eaten; largely chinch-bugs, taken by one of the birds. This fearful pest of the grainfields was sufficiently abundant in the vicinity of Normal this year sensibly to injure the crops of grain. Nearly all the species of birds examined were found to eat them to some extent, but in quantities so trifling as probably to have little or no effect upon their multiplication. It is evident, however, that the birds have no especial prejudice against them. The remainder of the Hemiptera were the ordinary "soldier-bugs," belonging to the genus Euschistus.

Orthoptera appear in somewhat larger ratio, amounting to seven per cent. of the food, an indication, doubtless, of the commencement of the autumnal multiplication of this order which will be found reflected to a very notable degree in the food of the bluebird further on. Only traces ef spiders and thousand-legs were discovered. Fifty-four parts of fruit were eaten, sixteen of which were wild. Nearly all of the garden fruits were blackberries,—cherries constituting but three per cent. of the food for the month.

September.

The catbird leaves our latitude in September, and only six specimens were secured,—all of them on or before the 17th, in the vicinity of Normal and Bloomington. The chief peculiarity of the food of the month is the substitution of cherries and wild fruits for blackberries. Seventy-six per cent. of the food at this time consisted of fruits, all wild but the grapes, which amounted to fourteen per cent. Elderberries, wild cherries and the fruit of the Virginia creeper were the most important elements. Carnivorous thousand-legs amounted to three per cent. of the food and insects proper to twenty-one per cent., nearly half of which were ants. But few caterpillars had been eaten by these birds, and only seven per cent. of Coleoptera,—five per cent. being Harpalidæ. The lower orders of insects were conspicuous only by their absence.

We are now prepared for the review of the general averages of the season, and the indications which these afford of the economic value of the catbird. Taking the record of the year together as found in the vertical column at the right of the table on pages 125, 126, 127, the seventy birds of the species examined are found to have eaten forty-three parts of insects, two parts of spiders and harvestmen, three parts of thousand-legs and fifty-two parts of fruits. Only thirty-three per cent. of the food consisted of tame fruits, four per cent. being raspberries, twenty per cent. blackberries, one per cent. currants, four per cent. tame cherries, one per cent. strawberries and three per cent grapes. Scrutinizing more closely the details of the insect food, we find that ants form twelve per cent. of the total for the season; Diptera, chiefly crane-flies, about five per cent.; Lepidoptera six per cent.; and beetles twelve per cent., one-third of which are Carabidæ. The scavenger beetles and leaf-chafers are three per cent. of the food; plant-beetles, one per cent., and snout-beetles, belonging chiefly to the leaf-eating Brevirostres, likewise one per cent. Two parts of Hemiptera and three of Orthoptera are the only other items that we need notice. It will be seen that ants and beetles occur in about equal ratios, and that these are the most important insect elements in the food. Diptera and Lepidoptera taken together about equal one of the former elements.

Recapitulation.

In the catbird as in the robin the insect averages are highest in the early months, and fall rapidly away from May to July,—rising again in August and declining in September. The ratios of insects taken for the five months covered by this table are as follows:—83, 49, 18, 46, 21. The same double curve is especially apparent in the averages of ants, the corresponding ratios for which are 18, 11, 2, 20, 9. Beetles gradually diminish to July and then remain tolerably constant for the season. The predaceous ground-beetles maintain themselves at nearly uniform figures throughout. The Scarabæidæ are, of course, most abundant in May and June, when the leaf-chafers are abroad. The snout-beetles observed were all taken in the months of May and June, and belonged chiefly to species whose injuries are confined to the leaves of trees. Only trifling ratios of plant-beetles were eaten by these birds. Hemiptera also occur in insignificant quantity, the only notable fact being the presence of chinch-bugs in the food of one bird. Orthoptera seemed to be most abundant in the late and early months, diminishing in June and July. Considerable numbers of Arachnida and Myriapoda are eaten by the catbird,—a point in which it contrasts notably with the robin. No earthworms were detected in the food. With respect to the fruits taken by this bird, we find that the general ratios for the corresponding months agree closely with those of the robin. Berries of the sumach are eaten in May, but raspberries and blackberries are the most prominent elements of June, July and August.

Wild cherries take the place of these fruits in September, and grapes are then eaten to some slight extent.

A comparison of the statements of this paper with the report published in the Transactions of the Illinois Horticultural Society for 1879, will give some interesting results. The former paper relates to thirty-seven specimens, obtained during the three months of May, June and July; and the present paper relates to seventy birds, taken during five months from May to September. As both the additional months extend the fruit season, we should expect the insect averages would now be smaller than before and that the averages of fruit would show a corresponding increase. This I find to be the principal difference between these tables. The various insect elements stand in about the same ratio to each other as before, except the ants (whose swarming in autumn accounts for their greater prominence in the food), and the Hemiptera and Orthoptera. The first of these orders figures more largely in the general averages for 1880 because this was a "chinch-bug year" in central Illinois; and the second because grasshoppers, locusts and crickets greatly increase in numbers during the later months. In the earlier table, insects amount to fifty-six per cent. of the food; in the later, only to forty-three; ants are respectively ten and twelve, Diptera thirteen and five, Lepidoptera ten and seven, Coleoptera nineteen and twelve, Carabidæ eight and five, leaf-chafers four and three, snout-beetles three and one, Hemiptera one and two, Orthoptera two and three, Arachnida three and two, Myriapoda six and three and the edible fruits twenty-seven and forty-one.

The Catbird and the Robin.

In order to a more exact comparison of the food-habits of the catbird and the robin, I have computed the averages of the principal elements of the robin's food for the period of five months covered by the catbird's record, and give these here alternately with the corresponding averages of the catbird. The ants eaten by the robin during these months amounted to five per cent. of the food, and those by the catbird to twelve per cent. Diptera were two per cent. and five per cent., Lepidoptera thirteen per cent. and seven per cent., Coleoptera thirteen and twelve, Carabidæ four and five, leaf-chafers three and two, wire-worms three and a trace, snout-beetles two and one, Hemiptera three and two, Orthoptera four and three, Arachnida a trace and two, Myriapoda a trace and three; raspberries and blackberries fourteen and twenty-four, cherries eighteen and twelve, currants three and one, grapes eleven and three, and strawberries—none by the robin and one per cent. by the catbird. From this it will be seen that the notable differences in the food-habits of these birds are the much larger ratios of ants, Diptera and berries eaten by the catbird; and of Lepidoptera, wireworms, cherries and grapes eaten by the robin. It also appears that the catbird has a much more hearty appetite for spiders and thousand-legs than the robin.

It is not likely that there is any such active competition for food between these two species as this close agreement in the kinds taken at the same place and season would imply. The stress of the robin's struggle for subsistence evidently comes in early spring, before the advent of the catbird; and by the time the latter appears there is probably an abundance of food for both species. The earlier departure of the catbird likewise prevents any stringent competition in the later months.

Economic Relations.

Remembering that the chief economic service of the robin is done before and after the midsummer wealth of fruits tempts it from the chase of insects, we find it not unreasonable that the catbird, coming later and departing earlier, scarcely anticipating the garden fruits in its arrival and disappearing when the vineyard and orchard are at their best, should be a much less useful bird than its companion. The credit I have given it must be still further reduced because of its serious depredations in the apple orchard. I have often seen it busily scooping out the fairest side of the ripest early apples, unsurpassed in skill and industry at this employment by the red-headed woodpecker or the bluejay.

At the bottom of the table of food given on page 127 a set of percentages will be seen similar to those previously mentioned in the discussion of the food of the robin. The beneficial elements eaten by this bird, including fruits and the carnivorous insects, run as follows, from May to September:—13, 53, 75, 45 and 19, the average for the season being forty-one per cent. The corresponding ratios of injurious elements are 29, 21, 7, 16, and 4, giving a general average of 15 per cent. for the year. Referring to the vertical column of figures at the right of the table we find the injurious insects of this bird's food as follows: saw-flies one per cent., Lepidoptera seven, leaf-chafers two, snout-beetles one, plant-beetles one, chinch-bugs one and Orthoptera three; while the beneficial insects in the same column are—predaceous beetles five, predaceous Hemiptera one, and Arachnida two. A careful comparison of these elements with each other will probably convince the intelligent reader that these insect averages balance each other fairly well, and that the injury done in the fruit-garden by these birds remains without compensation unless we shall find it in the food of the young. This statement is made upon the hypothesis that ants are to be regarded as neutral insects; and the entire question of the *immediate* value of this species, aside from the still unsettled question of the food of the young, may be reduced apparently to the following form: Will the destruction of a given quantity of ants pay for three times that quantity of the smaller garden fruits?

TABLE OF THE FOOD OF THE CATBIRD. (*Mimus carolinus*, L.)

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens..	..	..	..	..	22	19	11	12	6	..	..	..	07	
KINDS OF FOOD.	Number of specimens and ratio in which each element of food was found													
I. INSECTS..........	..	..	..	..	22 .83	19 .49	10 .18	12 .46	6 .21	..	..	..	69	.43
1. *Hymenoptera*	..	..	..	..	20 .22	13 .12	7 .04	12 .21	6 .09	..	..	..	58	.13
Formicidæ...	..	..	..	..	20 .18	13 .11	4 .02	11 .20	6 .09	..	..	..	54	.12
Ichneumonidæ	..	..	..	..	...	...	...	1 †	...	..	..	..	1	......
Tenthredinidæ	..	..	..	..	2 .02	1 .01	1 .02	...	...	..	..	..	4	.01
2. *Lepidoptera*	..	..	..	..	11 .14	8 .10	1 .03	3 .04	1 .04	..	..	..	24	.07
Caterpillars	..	..	..	..	10 .12	4 .05	...	2 .03	...	..	..	..	16	.04
Noctuidæ	..	..	..	..	1 .02	2 .02	...	1 .02	...	..	..	..	4	.01
3. *Diptera*	..	..	..	..	7 .20	5 .07	...	...	...	..	..	..	12	.05
Tipulidæ	..	..	..	..	6 .19	3 .07	...	...	...	..	..	..	9	.05
Bibionidæ..........	..	..	..	..	...	1 †	...	...	...	..	..	..	1	......
4. *Coleoptera*..........	..	..	..	..	13 .23	18 .17	8 .09	6 .06	4 .07	..	..	..	49	.12
Cicindela..........	..	..	..	..	...	...	1 †	...	...	..	..	..	1	......
Carabidæ	..	..	..	..	7 .09	3 .05	6 .07	2 .01	1 .05	..	..	..	19	.05
Dytiscidæ.........	..	..	..	..	2 .01	...	...	...	...	..	..	..	2	......
Hydrophilidæ.....	..	..	..	..	2 .03	...	...	...	...	..	..	..	2	.01
Staphylinidæ?.....	..	..	..	..	1 †	1 †	...	...	...	..	..	..	2	......
Phalacridæ........	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......
Nitidulidæ	..	..	..	..	...	1 †	1 †	...	...	..	..	..	2	......
Heteroceridæ	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......
Histeridæ.........	..	..	..	..	3 .01	1 †	...	...	...	..	..	..	4	......
Scarabæidæ.	..	..	..	..	1 .01	9 .10	3 .03	...	1 .01	..	..	..	14	.03

TABLE OF THE FOOD OF THE CATBIRD. (*Mimus carolinus*, L.)—Continued.

Kinds of Food.	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Total	Ratio of each element to whole of food.
Number of specimens..	..	..	..	..	22	19	11	12	6	..	..	..	70	
	Number of specimens and ratio in which each element of food was found													
Melolonthinæ ...	..	..	..	..	1 .01	5 .07	...	...	...	..	..	..	6	.02
Euryomia.......	..	..	..	..	1 †	...	...	...	...	..	..	.	1	......
Elateridæ.........	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......
Lampyridæ	..	..	..	..	3 .01	1 †	...	...	...	..	..	..	4	......
Tenebrionidæ	..	..	..	..	1 †	1 †	...	...	...	..	..	..	2	......
Meloidæ	..	..	..	..	...	...	1 .01	...	...	..	..	..	1	......
Rhyncophora	..	..	..	..	6 .05	2 .01	...	...	...	..	..	..	8	.01
Brevirostres.....	..	..	..	..	4 .04	...	...	...	...	..	..	..	4	.01
Longirostres.....	..	..	..	..	2 .01	...	...	...	...	..	..	..	2	......
Chrysomelidæ.....	..	..	..	..	3 .01	2 .01	2 .01	...	...	..	..	..	7	.01
Coccinellidæ	..	..	..	..	...	1 †	...	...	...	..	..	..	1	......
5. *Hemiptera*..........	..	..	..	..	2 †	2 .01	1 †	7 .07	...	..	..	..	12	.02
Blissus............	..	..	..	..	...	...	...	1 .05	...	..	..	..	1	.01
Pentatomidæ......	..	..	..	..	2 †	2 .01	...	2 .02	...	..	..	..	6	.01
6. *Orthoptera*	..	..	..	..	6 .04	3 .02	1 .01	5 .07	...	..	..	..	15	.03
Diapheromera.....	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......
Gryllidæ..........	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......
Acrididæ.........	..	..	..	..	3 †	3 .02	...	4 .07	...	..	..	..	10	.02
7. *Neuroptera*.........	..	..	..	..	...	1 †	...	...	1 .01	..	..	..	2	......
II. ARACHNIDA	..	..	..	..	7 .03	3 .03	2 .04	1 †	...	..	..	..	13	.02
III. MYRIAPODA....	..	..	..	..	6 .07	2 .03	4 .04	1 †	2 .03	..	..	..	15	.03
Chilopoda.............	..	..	..	..	1 †	...	...	...	...	..	..	..	1	......

TABLE OF THE FOOD OF THE CATBIRD. (*Mimus carolinus*, L.)—Concluded.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens	..	..	..	..	22	19	11	12	6	..	..	..	70	
KINDS OF FOOD.	Number of specimens and ratio in which each element of food was found.													
Diplopoda	..	..	..	..	6 .07	2 .03	4 .04	1 †	2 .03	..	..	..	15	.03
IV. FRUITS	..	..	..	..	2 .07	13 .45	10 .74	12 .54	6 .76	..	..	..	43	.52
Strawberries	..	..	..	..	...	2 .03	...	...	...	..	..	..	2	.01
Raspberries	..	..	..	..	...	9 .21	...	...	...	..	..	..	9	.04
Blackberries	..	..	..	..	...	...	10 .64	8 .35	...	..	..	..	18	.20
Currants	..	..	..	..	...	1 .04	...	...	...	..	..	..	1	.01
Cherries	..	..	..	..	...	6 .16	...	1 .03	3 .40	..	..	..	10	.12
Grapes	..	..	..	..	...	...	...	...	1 .14	..	..	..	1	.03
Sumach	..	..	..	..	2 .07	...	...	...	...	..	..	..	2	.01
Ampelopsis	..	..	..	..	...	...	...	1 .02	1 .04	..	..	..	2	.01
Elderberries	..	..	..	..	...	...	...	...	3 .15	..	..	..	3	.03
	Percentages for each month.													
Beneficial elements	..	..	..	..	13	53	75	45	19	..	..	..	....	41
Injurious elements	..	..		..	29	21	07	16	04	..	..	..	....	15
Neutral elements	..	..	..	..	58	26	18	39	77	..	..	..	....	44

HARPORHYNCHUS RUFUS, L. BROWN THRUSH.

The brown thrush, although not so common a bird as the two preceding species, is still abundant enough to make its habits a matter of economic interest, both to the gardener and the farmer. It is reported by Baird, Brewer and Ridgway to reside and breed all over the United States east of the Rocky Mountains, but in this state it is, like the robin and catbird, practically a strict migrant. Mr. E. W. Nelson reports its occasional occurrence in southern Illinois in midsummer. It reaches Bloomington a little earlier than the catbird, and, like that species, leaves us in September. It is a shyer bird than either of the preceding, shrubbery and thickets being its favorite haunts and nesting-places.

April.

The record opens with fourteen specimens taken from the 8th to the 28th of April. Five of them were from central Illinois and nine from the northern part of the state, in Lake and JoDaviess counties. Fifty-one per cent. of the food of these birds consisted of insects, two per cent. of spiders and six per cent. of thousand-legs. Seven per cent. of the food was Hymenoptera, nearly all ants; five parts were caterpillars and five were grubs of Diptera,—apparently crane-flies. Beetles make about one-fourth of the food, and one-fifth of these were Carabidæ. Platynus, Agonoderus and Harpalus were the only genera recognized. A remarkable feature of the food was the occurrence of four per cent. of carrion-beetles, chiefly *Silpha lapponica* and *S. americana*. Thirteen per cent. of the food of the month consisted of Scarabæidæ, about three-fourths of these belonging to the genus Euryomia, which eats the leaves of fruit trees later in the season. A few June beetles were also taken at this time. A trace of wire-worms, three per cent. of snout-beetles (about two-thirds of them Brevirostres), one per cent. of Hemiptera and two per cent. Orthoptera were the remaining insect elements. We come next to the distinctive feature of the food of this bird among all the thrushes. Forty-one per cent. of the food consisted of seeds and fragments of grain, of which about one-seventh was acorns taken by woodland specimens, and nearly all the remainder corn. The appearance and odor of the contents of these stomachs left no doubt that the fragments mentioned were picked from the excrement of animals.

May.

The month of May is represented also by fourteen specimens, taken at various dates from the 1st to the 27th, chiefly early in the month. Eleven of these were shot in the northern part of the state, between Galena and Waukegan. The large percentage of insect food in May reminds us of the corresponding rise, in this month, of the insect averages of the food of the robin and the catbird. Seventy-nine per cent. of the food of these birds consisted of insects proper, only one per cent. of spiders and three per cent. of thousand-legs. Ants now amount to four per cent., caterpillars to twelve per cent. (one-third of them distinguishable as cutworms), and Coleoptera to precisely one-half the food, one-tenth of it being Carabidæ.

Scarabæidæ rise to thirty-five per cent., chiefly June-beetles of the genus Lachnosterna, wireworms to three per cent. and Hemiptera and grasshoppers likewise to three per cent. The Hemiptera were all soldier-bugs. Among the predaceous beetles Pterostichus, Anisodactylus and Harpalus were recognized. A single specimen of *Cytilus sericeus* was the only representative of the family Byrrhidæ found in the food of any of these birds. Corymbetes and *Monocrepidius auritus* were among the spring-beetles taken. In this month, as in the preceding, the snout-beetles were chiefly Brevirostres. The Scarabæidæ included *Onthophagus hecate*, *Aphodius fimetarius*, *inquinatus* and *granarius*, and *Euryomia inda*. Seventeen per cent. of the food of the month consisted of fragments of grain.

June.

The birds of June, fifteen in number, taken from the 1st to the 29th, all from the northern part of the state but two, had eaten about equally of insects and vegetable substances. Ants rise in this month to eleven per cent., caterpillars fall to three, about one-third of these being cutworms. Diptera fall to one, and Coleoptera to twenty-seven per cent., and Carabidæ drop likewise to four per cent. Scarabæidæ return to seventeen, thirteen of these being leaf-chafers; wireworms fall to one, snout-beetles rise to four, and plant-beetles are represented by a single *Chrysomela suturalis*. Among the snout-beetles occur *Sphenophorus parvulus* and *S. sculptilis*. Several specimens of *Epicærus imbricatus* were eaten by three birds. *Phanæus carnifex*, *Onthophagus hecate* and *Aphodius fimetarius* appear among the Scarabæidæ. The commencement of the fruit season is here distinctly discernible. Twenty-two per cent. of the food of these birds consists of raspberries, five per cent. of strawberries and one per cent. of cherries, making a total of twenty-nine per cent. of fruits. Fragments of corn and oats amount to nineteen per cent.

July.

But seven birds were examined in July; all from the vicinity of Normal. All of these had eaten insects, which amounted to only about one-fourth of the food. Both ants and caterpillars were present in trifling quantity. Only about half as many Coleoptera had been taken as in the month preceding. Hemiptera and Orthoptera each make up four per cent. of the food, and Arachnida and Myriapoda are entirely wanting. Carabidæ stand at four per cent., as in June, spring-beetles continue at three and snout-beetles amount to two per cent. *Evarthrus colossus* was found among the Carabidæ. *Heteraspis pubescens*, *Colaspis brunnea* and *Diabrotica 12-guttata* represented the plant-beetles. The fruits of July amounted to sixty-two per cent. of the food,—all blackberries. Twelve per cent. consisted of fragments of corn.

August.

Twelve birds were shot in August, all from McLean county, at various times in the month from the 7th to the 30th. The insect averages rally again in August, returning now to fifty-one per cent. Hymenoptera rise to fourteen per cent.,—the highest average of the season,—a fact due doubtless to the swarming of certain species of ants at this time of the year.

Caterpillars amount to eleven per cent. of the food; Coleoptera fall away to ten, and all but one of these are Carabidæ. *Cratacanthus dubius* seems to be especially abundant in the later summer and early autumnal months. Four per cent. of the food of these birds consists of this species, and it has likewise been found prominent in the food of the bluebird and the catbird at the same season of the year. A small percentage of snout-beetles and plant-beetles call for no special remark. Hemiptera now make one-tenth of the food—an exceptional occurrence due to the fact that this was one of the chinch-bug years in central Illinois and that three of these birds had eaten freely of that insect. Orthoptera stand at six per cent., about equally distributed between the three families of the crickets, locusts and grasshoppers. A specimen of Tridactylus was noticed among the first and one of the common katydids among the second. The fruits of this month amount to thirty per cent., eaten by nine of the birds. Half of these were cherries, and the remainder were blackberries, grapes, elderberries, and the berries of the mountain-ash. Fragments of corn amounted to eighteen per cent. of the food.

September.

But two birds were shot in September, too few to give any correct idea of the food of the month. It is only necessary to say that these had eaten more largely of grasshoppers than the birds of the preceding month, and to about the same extent of fruits, all of which were grapes.

Summary for the Year.

Taking the food of the year together, we find that almost precisely one-half of it consisted of insects. Spiders amounted to but one per cent. and thousand-legs to but three. The remainder of the food consisted equally of the smaller garden fruits and the fragments of seeds and grain. Thirteen per cent. of the food of these sixty-four birds consisted of blackberries, four per cent. of raspberries, one per cent. of strawberries and three per cent. of cherries. The ants of the year stand at seven per cent., caterpillars at six, and Diptera at only one. Coleoptera amounted to precisely one-fourth of the food, predaceous beetles to six per cent. and Scarabæidæ to thirteen per cent., nearly all of these being leaf-chafers. Spring-beetles and snout-beetles each average two per cent., and Hemiptera and Orthoptera each stand at four.

In the paper previously cited, published in the Transactions of the Illinois Horticultural Society for 1879, I gave a table of the food of this species based upon twenty-eight specimens shot in April, May, June and July. A test of the substantial correctness of the conclusions of the present paper may be made by comparing the averages of the table printed herewith with the table on page 150 of the Transactions cited. If the important ratios of the present table, covering the food of sixty-four specimens, shot during six months of the year, agree substantially with that table of the food of twenty-eight specimens, covering but four months of the year, this will be sufficient evidence of their general correctness I will give these averages alternately, first for the former table and then for the present. The twenty-eight specimens of 1879 had eaten insects to the amount of fifty-nine per cent., and sixty-four specimens of the table of 1880 had eaten insects to the amount of fifty-one per cent. Hymenoptera are seven in the first and eight in the second; ants are seven in the first and also in the second; Lepidoptera seven and seven, Diptera a trace and one, Coleoptera twenty-nine and twenty-five, Carabidæ six and six, Silphidæ two and one; leaf-chafers nine and ten, spring-beetles one and two, snout-beetles three and two, Hemiptera two and four, Orthoptera four and four, Arachnida one and one, Myriapoda four and three, and fruits twenty-two and twenty-four. A larger percentage of Hemiptera is due to the much greater abundance of chinch-bugs in 1880.

Recapitulation.

The brown thrush, arriving in April, finds nearly one-half of its food in fragments of corn and other grains and seeds picked from the droppings of animals. This curious habit it maintains throughout the year, evidently taking this food from preference as well as from necessity. In fact I have often found these vegetable fragments associated with blackberries in the food.

After April this element averages about sixteen per cent. throughout the season. Insects amount to about half the food for each month, except in May when they rise to three-fourths and in July when they drop to one-fourth. The excess in May occurs at the time of the greatest number and activity of the beetles, and the diminution in July coincides with the period of the greatest abundance of the small fruits. One-half the insects eaten are beetles, which stand at one-fourth of the food in April and June, rise to one-half in May and fall to about one-eighth in July and August. Half the beetles of the year are Scarabæidæ, chiefly June beetles and Euryomia, all taken previous to July. Nearly one-fourth of the beetles are Carabidæ, which remain at about five per cent. of the food, except in May when they rise to ten per cent. Although the ratios of spring-beetles and snout-beetles are but two per cent., the numbers eaten are of some significance. My notes show that these birds were eating each at the daily rate of about 1½ curculios, and consequently had averaged a total of about 250 to each thrush for the season. The brown thrush takes ants more freely than the robin, but eats comparatively few caterpillars; seven per cent. of each were found in the food of the year. Diptera are taken in very trivial quantity and Hemiptera in moderate number only. This bird eats thousand-legs more freely than the robin, especially in the early spring. In the garden it plays a part very similar to that of the other thrushes, but is less mischievous, on the whole. Its average of the edible fruits for June, July and August is thirty-eight per cent. as against sixty per cent. of the robin and forty-nine per cent. of the catbird. It relishes the whole list of garden fruits, and later in the season resorts, like the other thrushes, to the wild fruits of the woods and thickets. Compared with the robin, this bird is seen to be especially peculiar in the coprophagous habit already mentioned as distinguishing it from all the other thrushes. It takes about one-half as many Lepidoptera, about half as many again Coleoptera, nearly twice as many Carabidæ and three times as many leaf-chafers; but eats comparatively few grapes and cherries. From the catbird it is further distinguished by taking half as many ants, a trivial number of Diptera, twice as many Coleoptera and twice as many Carabidæ, five times as many leaf-chafers and more spring-beetles, snout-beetles, Hemiptera and Orthoptera. It eats two-thirds as many berries and one-third as many cherries and grapes as the catbird.

Economic Value.

Compared with the robin for corresponding months, this species seems to show very similar economic relations. In both, the totals of beneficial elements eaten during this period are to the injurious about as four to three; but with the brown thrush as with the catbird, its later arrival and earlier departure are to its disadvantage. Balancing as carefully as I can its seven parts of Lepidoptera, ten of leaf-chafers, two of spring-beetles, two of snout-beetles, one of chinch-bugs and four of Orthoptera on the one hand, against its six parts of Carabidæ, two of predaceous Hemiptera, one of spiders, one of predaceous thousand-legs and twenty-one of small fruits on the other, I cannot see that, so far as the *immediate* consequences of its food habits are concerned, it does more good than harm. In short, its Orthoptera must pay for its garden fruits; that is to say, eliminating these two elements, I judge that the predaceous insects eaten would destroy during the year about as many injurious insects as the bird itself has taken. However, I must repeat the suggestion that they could hardly destroy the *same kinds* as the bird, and that, if allowed to live, they would probably decimate some species already sufficiently restricted by existing checks, and permit an unrestrained increase of others now kept down by the thrush. That the disturbances thus set up would soon lead us to regret this bird if its numbers were greatly lessened, is therefore very probable, and I believe the species should be preserved. We must not overlook the special services of the brown thrush in devouring a much larger number of June-beetles than any other of the species examined.

TABLE OF THE FOOD OF THE BROWN THRUSH. (*Harporhynchus rufus*, L.)

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens	..	..	..	14	14	15	7	12	2	..	..	..	64	
KINDS OF FOOD.	Number of specimens and ratio in which each element of food was found													
I. MOLLUSCA	..	..	..	...	1 †	...	...	1 †	..	..	..	..	2	†
II. INSECTA	..	..	..	14 .51	14 .79	15 .49	7 .26	12 .51	..	..	..	..	62	.51
1. *Hymenoptera*	..	..	..	9 .07	10 .04	11 .12	4 .02	11 .14	..	..	..	..	45	.08
Formicidæ	..	..	..	8 .06	10 .04	10 .11	3 .02	11 .14	..	..	..	..	42	.07
Ichneumonidæ	..	..	..	2 †	...	1 †	...	...	..	..	..	..	3	....
2. *Lepidoptera*	..	..	..	6 .05	12 .12	6 .03	2 .03	7 .11	..	..	..	..	33	.07
Caterpillars	..	..	..	6 .05	12 .12	4 .02	...	7 .11	..	..	..	..	29	.06
Noctuidæ	..	..	..	...	4 .04	2 .01	...	...	..	..	..	..	6	.01
3. *Diptera*	..	..	..	1 .05	...	2 .01	...	...	..	..	..	..	3	.01
4. *Coleoptera*	..	..	..	12 .26	14 .50	14 .27	7 .13	9 .10	..	..	..	..	56	.25
Carabidæ	..	..	..	9 .05	7 .10	5 .04	3 .04	5 .09	..	..	..	..	29	.06
Silphidæ	..	..	..	3 .04	...	...	...	...	..	..	..	..	3	.01
Nitidulidæ	..	..	..	...	...	...	1 .02	...	..	..	..	..	1	†
Staphylinidæ	..	..	..	...	1 †	...	...	...	..	..	..	..	1	†
Histeridæ	..	..	..	2 †	3 .01	1 †	...	1 †	..	..	..	..	7	†
Byrrhidæ	..	..	..	...	1 †	...	...	...	..	..	..	..	1	†
Scarabæidæ	..	..	..	9 .13	11 .35	8 .17	...	1 †	..	..	..	..	29	.13
Melolonthinæ	..	..	..	2 .01	6 .26	4 .13	...	...	..	..	..	..	12	.08
Euryomia	..	..	..	2 .09	2 .03	...	...	...	..	..	..	..	4	.02
Buprestidæ	..	..	..	...	...	1 †	...	...	..	..	..	..	1	†
Elateridæ	..	..	..	1 .01	8 .03	3 .01	3 .03	...	..	..	..	..	15	.02
Tenebrionidæ	..	..	..	...	...	...	1 .01	...	..	..	..	..	1	†

TABLE OF THE FOOD OF THE BROWN THRUSH. (*Harporhynchus rufus*, L.)
Continued.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens..	..	..	..	14	14	15	7	12	2	..	..	..	64	
KINDS OF FOOD.	Number of specimens and ratio in which each element of food was found													
Lampyridæ	..	..	..	...	...	1 †	...	...	..	..	..	...	1	†
Rhynchophora	..	..	..	7 .03	5 .01	7 .04	3 .02	3 .01	..	..	.	...	25	.02
Brevirostres.....	..	..	..	3 .02	...	3 .02	1 .01	2 .01	..	..	..	...	9	.01
Longirostres.....	..	..	..	3 .01	1 †	2 .01	...	1 †	..	..	..	...	7	†
Brenthidæ	..	..	..	...	...	1 †	...	...	..	..	..	...	1	†
Chrysomelidæ.....	..	..	..	...	...	1 †	2 .01	1 †	..	..	..	...	4	.01
5. *Hemiptera*..........	..	..	..	3 .01	6 .03	1 .01	5 .04	6 .10	..	..	..	...	21	.04
Blissus............	..	..	..	...	...	...	...	3 .06	..	..	..	...	3	.01
Pentatomidæ......	..	..	..	...	6 .03	1 .01	3 .02	...	..	..	..	...	10	.01
6. *Orthoptera*	..	..	..	1 .02	4 .04	3 .05	2 .04	4 .06	..	..	..	...	14	.04
Gryllidæ..........	..	..	..	...	...	...	1 .02	1 .02	..	..	..	...	2	.01
Locustidæ.........	..	..	..	...	...	...	...	1 .01	..	..	..	...	1	†
Acrididæ..........	..	..	..	1 01	3 .03	3 .04	...	1 .01	..	..	..	...	8	.02
III. ARACHNIDA	..	..	..	3 .02	1 .01	1 .01	...	...	..	..	..	...	5	.01
IV. MYRIAPODA.......	..	..	..	6 .06	7 .03	5 .03	...	1 .01	..	..	..	...	19	.03
Geophilidæ	..	..	..	1 .01	...	...	...	1 .01	..	..	..	...	2	.01
Iulidæ	..	..	..	5 .05	7 .03	5 .03	...	...	..	..	..	...	17	.02
V. FRUITS	..	..	..	...	...	9 .29	6 .62	9 .30	..	..	..	...	24	.24
Blackberries	..	..	..	...	...	...	6 .62	1 .05	..	..	..	...	7	.13
Raspberries.......	..	..	..	...	...	6 .22	...	...	..	..	..	...	6	.04
Strawberries.......	..	..	..	...	...	3 .05	...	...	..	..	..	...	3	.01
Grapes...........	..	..	..	...	...	...	...	2 .02	..	..	..	...	2	†

TABLE OF THE FOOD OF THE BROWN THRUSH. (*Harporhynchus rufus*, L.) Concluded.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens	..	..	..	14	14	15	7	12	2	..	..	..	64	
KINDS OF FOOD.	Number of specimens and ratio in which each element of food was found.													
Cherries	..	..	..	...	...	1 .01	...	3 .15	..	..	..	..	4	.03
Elderberries	..	..	..	...	...	...	...	1 .04	..	..	..	..	1	.01
Mountain-ash	..	..	..	...	...	...	...	1 .03	..	..	..	..	1	.01
VI. SEEDS AND GRAIN	..	..	..	12 .41	7 .17	9 .18	1 .12	5 .18	..	..	..	..	34	.21
Acorns	..	..	..	2 .06	...	...	...	...	..	..	..	..	2	.01
Oats	..	..	..	...	...	2 .01	...	...	..	..	..	..	2	†
Corn	..	..	..	9 .34	...	6 .17	1 .12	5 .18	..	..	..	..	21	.16
Wheat	..	..	..	1 .01	...	...	...	...	..	..	..	..	1	†
Buckwheat	..	..	..	1 †	...	...	...	...	..	..	..	..	1	†
	Percentages for each month.													
Beneficial elements	..	..	..	9	14	34	70	36	...	..	..	..	....	33
Injurious elements	..	..		21	49	25	13	24	..	..	..	..	....	26
Neutral elements	..	..	..	70	37	41	17	40	..	..	..	..	....	41

TURDUS MUSTELINUS, Gm. WOOD THRUSH.

The remaining members of this family are much less important than the preceding species, and their food is of relatively little interest. I shall therefore treat them much more briefly, especially as I have comparatively few specimens of them. The wood thrush is essentially a woodland bird, but occurs not infrequently in groves and gardens and in other situations where trees and shrubbery are accessible. It reaches central Illinois in April, and retires usually in October, spending its winter in the Southern States. I have studied the food of but twenty-two specimens of this species, ranging from April to September.

Two of these birds were taken in April, five in May, six in June, six in July, two in August and one in September. I shall not attempt to follow the food of the species through these months, or to give its seasonal variations; but will content myself with a general statement of the food of the year as indicated by the contents of the stomachs of these twenty-two birds. Seventy-one per cent. of their food consisted of insects and twenty per cent. of fruit, a small ratio of spiders and mollusks and an unusually large percentage of Myriapoda making up the remainder. The four higher orders of insects occur in about equal quantities, the proportion of ants and crane-flies being extraordinary. Blackberries, strawberries, cherries and gooseberries appear among the fruits. Myriapoda amount to twelve per cent.—nearly all Polydesmus and Iulus. The two parts of Arachnida included a few harvest-men. Orthoptera and Hemiptera are respectively six and one per cent.; and snout-beetles and wireworms thirteen per cent. A few June-beetles had been taken, and one of the birds from northern Illinois had stuffed itself with rose-beetles (*Macrodactylus subspinosus*). Geotrupes and Onthophagus were noticed among the other Scarabæidæ. The Carabidæ amounted to six per cent. of the food, including Evarthrus, Pterostichus, Harpalus, Anisodactylus and Bradycellus. Coleoptera make eighteen per cent. of the food and Diptera twelve per cent., chiefly crane-flies and the larvæ of *Bibio albipennis.* Lepidoptera were taken in about the same amount, one-third being recognized as cutworms, while ants reached the unusual average of fifteen per cent. *Helix labyrinthica*, *Pupilla fallax* and a few other univalve mollusks made one per cent. of the food. Compared with other Turdidæ, we find the general insect average unusual, exceeding that of the robin. It agrees with, and even surpasses, the catbird in its preference for ants; and with the robin in the ratios of Lepidoptera, Diptera, Coleoptera, Carabidæ and Scarabæidæ. It differs from the robin in its taste for ants and in the smaller ratio of fruits; and far surpasses all the other thrushes in the number of Myriapoda eaten in spring. In fact, the midsummer fruits seem to replace these spring Myriapoda, instead of insects proper as in the species already discussed. This bird apparently contrasts more directly with the brown thrush in food than with any other member of the family. The large percentage of Orthoptera is misleading, being due to the fact that a single bird had taken nothing but grasshoppers and locusts. This species seems to do more good and less harm than the preceding thrushes, having the lowest fruit ratio and eating the highest number of insects, with only the average of predaceous species. Its advances, therefore, are to be cordially encouraged by the gardener and farmer—a fact which must be especially agreeable to every lover of bird music, who has learned to recognize the full, clear, rich and exquisite strains of this songster.

HYLOCICHLA PALLASI, Cab. HERMIT THRUSH.

The hermit thrush is strictly a migrant, passing us in May and October. It is reported by Mr. Ridgway as a rare winter resident in southern Illinois, but otherwise appears in the state only during its passage to and fro. Considering the fact, however, that all these birds travel slowly the whole length of the state, merely keeping pace with the advancing and retreating seasons, and also that the species is a very abundant one at the period of the migrations, it will be seen that its food has great economic significance. There is reason to suppose that these migrants, in passing north and south, follow, year after year, about the same route; do not vary, that is, far to the east or west. Consequently, occupying as we do a state that lies in five and one-half degrees of latitude, we can do much to protect this species in its wanderings, or can, if we choose, almost entirely eliminate that part of it passing over our territory. Twenty-one hermit thrushes were taken during the year, two in October and the remainder during the spring migrations. All but five of these birds were shot in extreme northern Illinois, at Waukegan, Evanston and Blue Island. Eighty-four per cent. of the food consisted of insects, four per cent. of spiders and twelve per cent. of thousand-legs. Ants amounted to fifteen per cent., Lepidoptera to nineteen per cent., including a few Phalænidæ, and Diptera only to three—chiefly the larvæ of Bibio.

Coleoptera make thirty per cent. of the food, eleven per cent. being Carabidæ. *Dyschirius globulosus*, Platynus, Evarthrus, Pterostichus, Amara, *Anisodactylus discoideus*, Bradycellus and Stenolophus are mentioned in my notes. Four per cent. are water-beetles, five per cent. scavenger-beetles, two per cent. curculios and two per cent. plant-beetles. Leaf-chafers and spring-beetles amount to one per cent. each—the latter chiefly of the genus Melanotus. *Lixus concavus* and *Listronotus inæqualipennis* occur among the curculios, and *Chrysomela suturalis*, *Gastrophysa dissimilis* and *Plagiodera viridis* among the plant-beetles. Eight per cent. of the food was Hemiptera, nearly all of which were predaceous. *Podisus spinosus* was the only species determined. Grasshoppers (Tettix and Tettigidea) make seven per cent. of the food. Respecting the number of beetles eaten by this bird, we have to remember that it passes us at the time of that great outpouring of insect life connected with the pairing of the spring Coleoptera which we have already seen to have a very significant relation to the food of birds. It rides northward, in fact, on the crest of this Coleopterous wave, and we find the same excess of predaceous Coleoptera in its food which occurs in the food of the other thrushes at the same season. Concerning the two October specimens taken in northern Illinois I need only say that they had eaten ants, caterpillars, Carabidæ, curculios, Pentatomidæ and Orthoptera, spiders, Iulidæ and the larvæ of Bibio. The habits of this bird suggest that the principal drain on the numbers of predaceous beetles may be due to the depredations of the migrants, at the season of the greatest exposure of these insects; and that the complete destruction of resident birds would affect the number of these carnivorous insects much less than would at first seem likely. The reader curious to see the points in which this species contrasts with the other thrushes, may consult the table of the food of the family on page 147.

TURDUS ALICIÆ, Bd. ALICE THRUSH.

The Alice thrush is a bird of frequent occurrence during the migrations. It breeds far to the north, rare summer stragglers occuring in northern Illinois, according to Mr. E. W. Nelson, and probably winters quite beyond our limits. By Dr. Coues this is regarded merely as a variety of the following species. I have ten specimens of this bird shot in May, but none from the fall migration. This number is probably sufficient, however, to give a fairly correct idea of its food in spring. Five per cent. of the food of the month consisted of mollusks, chiefly Succinea and *Helix labyrinthica*; ninety-three per cent. was insects and nearly half of these were ants, which reached the astonishing ratio of forty-three per cent., eaten by every one of the birds. Fifteen per cent. of the food was caterpillars; nine per cent. consisted of crane-flies and their larvæ: Coleoptera amounted to eighteen per cent. (one-half Aphodiidæ), and the remainder were wireworms curculios and plant-beetles. Carabidæ amounted only to one per cent., the lowest average of these beneficial insects found in the food of any thrush. Among the species of Coleoptera we find *Stelidota geminata*, *Onthophagus janus*, *Conotrachelus anaglypticus*, *Chrysomela suturalis* and *C. similis*. Grasshoppers make three per cent. of the food and Myriapoda two per cent., all *Polydesmus serratus* and undetermined Iulides. Of spiders merely a trace was found in the stomachs of two birds. The striking feature of the food of this bird is evidently its enormous appetite for ants, its high insect average and the almost total absence of beneficial elements in its food giving to this little thrush an enviable status in relation to the farm and garden.

TURDUS SWAINSONI, Cab. SWAINSON'S THRUSH.

This is a migrant of which I have too few specimens for generalization. Six in April and May were taken at Warsaw, Waukegan and Normal, and five in September from the vicinity of Cairo, in extreme southern Illinois, and northern Kentucky. The food in spring is very like that of the preceding species, its especial features being the large number of ants and caterpillars and Coleoptera. The September specimens, on the other hand, were feeding largely upon fruits, which constituted sixty per cent. of their food. Wild grapes, wild cherries, elderberries and blackberries were all eaten by them, grapes alone making more than half their food. Hymenoptera amounted to nineteen per cent. of the whole; ants to seven, caterpillars to twelve, crane-flies to four, and Coleoptera to eighteen per cent.; five per cent. were Carabidæ (including Anisodactylus), three per cent. were leaf-chafers and two per cent. were curculios. One of the birds, taken at Warsaw in April, had eaten little else than *Scolytus muticus*. Two per cent. of the food was Hemiptera, chiefly Pentatomidæ and Reduviidæ; Rhynchophora and Hemiptera made two and one per cent. respectively. Of spring-beetles and Aphodiidæ, only a trace had been eaten by two of the birds.

MIMUS POLYGLOTTUS, L. MOCKING-BIRD.

This famous bird, not many years ago regarded as a rarity in the state, is evidently becoming more abundant, and is also extending its habitat northward. Collectors in the southern part of the state agree to its increasing numbers there. Three specimens were seen this year in the vicinity of Bloomington, two of which were secured. One of these, shot in August, was of this year's brood, and as the other two seemed thoroughly habituated, it is likely that they had nested in this vicinity this season. It may be worth while to note that sixty per cent. of the food of these two specimens consisted of Orthoptera, including the climbing cricket (Œcanthus). Besides these, they had eaten spiders and harvest-men, Coleoptera, Hemiptera and ants. Among the Coleoptera were specimens of Onthophagus, *Epicauta vittata* and long-snouted curculios. The Hemiptera were undetermined Coreidæ and Pentatomidæ. These birds had not eaten fruit, although the species is reported to be especially fond of grapes.

CONCLUSION.

As a very general statement of the peculiarities of the food of the resident species, we may say that the robin is characterized by its destruction of caterpillars (especially cutworms) and the larvæ of Bibio, by its neglect of ants, spiders and Myriapods, and by its taste for blackberries grapes, and especially cherries; that the catbird is distinguished by the large number of ants, blackberries and cherries eaten, and by the small number of insects generally, and of Lepidoptera, Coleoptera and Hemiptera in particular; that the brown thrush is noted for its coprophagous habit, for the small number of caterpillars and Diptera taken, for the large percentage of phytophagous Scarabæidæ and the moderate ratio of small fruits; and that the wood thrush differs from the others chiefly in the large percentage of insects (especially ants, caterpillars and crane-flies), its indifference to Hemiptera and preference for Orthoptera and Myriapoda, and its smaller ratios of fruits.

The migrants can be properly compared only with the residents during the migrating season. I have consequently made a table of the percentages of the food of the four resident species for April and May in comparison with the spring food of the three migrants. From this we learn that the hermit thrush is distinguished at this season by the moderate ratio of ants and Coleoptera, the large number of Lepidoptera, Hemiptera, Orthoptera, spiders and Myriapoda, and the small percentage of Diptera taken. The Alice thrush eats mollusks, an enormous number of ants, a moderate number of Lepidoptera, Diptera and Scarabæidæ, and a small number of Carabidæ and Coleoptera generally, while Hemiptera are almost wanting in its food. Swainson's thrush takes large ratios of ants, Lepidoptera and Coleoptera, and small ratios of Hemiptera, Orthoptera, Arachnida and Myriapoda. It is not to be supposed that the number examined of the last two species is sufficient to give more than an approximate and doubtful outline of the food.

Indeed the reader may not unlikely receive with incredulity the precise statements made concerning the food characteristics of the resident species, and ask how it can be known that these peculiarities are specific and constant instead of local and accidental. To this very reasonable query I am able to make a definite answer. In the paper already frequently cited, I published a comparative table of food of the species of this family, based on the contents of the stomachs of one hundred and forty-nine birds,* up-

*Trans. Ill. Hort. Society, 1879, N. S., Vol. 13, p. 163.

on which table certain differences of food are clearly shown. Now, if these differences were local and accidental, they would undoubtedly tend to disappear when larger numbers of specimens were examined; but if they are specific and constant, they should be made the more evident, on the whole, the larger the number of specimens taken. The table on page 147 presents data derived from three hundred and fifteen specimens, covering considerably more time and area than the table in the Transactions. If the difference between the food records of the various species are now greater than before, we may conclude that the differences noted are real and not artificial. If they are less, on the other hand, the whole question is still unsettled. The differences apparent in the later table may be specific, but there is no proof of it. In order to apply this crucial test as fully as possible, I have selected twelve food elements in which the differences were most apparent, and, taking the species in pairs, have ascertained the sum of the differences of the ratios of these elements for each pair separately, first from the old table and then from the new. In every case but one the sum of these differences has been much larger by the new table than by the old, thus proving conclusively that the species appear to diverge in food habits the more widely the greater the number of specimens studied. For example, the differences of the selected elements as shown in the original table of seventy-eight robins and catbirds, amounted to sixty-four per cent.; and by the new table of one hundred and eighty-four birds, to eighty-two per cent. A similar comparison of the food of the catbird and hermit thrush gives one hundred and twenty-five as the sum of the differences of the old table of fifty-five birds, and one hundred and fifty-five as the sum of the differences of the new table of ninety-one birds. Taking the catbird and the brown thrush, we have sixty-four and ninety-nine parts for the old and new tables respectively, the first for sixty-five birds and the second for one hundred and thirty-four; while the brown thrush and wood thrush give seventy-eight and eighty-eight parts for thirty-nine and eighty-six birds respectively, and the catbird and wood thrush give seventy parts for eighty-five birds and eighty-three parts for ninety-two birds. It is not until we reach the last two migrants that we find any exception to these results: and of these, as already said, probably too few have been examined, even yet, to justify settled conclusions.

Finally, we must consider the family as a unit, must discuss the actual effect of the thrushes as a group upon the plants and animals of the state. A determination of this interesting question involves three elements; the average character of the food of each species as shown by the preceding calculations, the comparative abundance of the species, and the length of its stay in Illinois. I find the estimates of the second of these elements, as made by various collectors, to differ rather widely; and on this account only an approximate conclusion can be reached. Using the figures most satisfactory to myself, I present the following as a tolerably fair statement of the general food of the family: Sixty-one per cent. of the food consists of insects, one per cent. of spiders, two per cent. of Myriapods, and thirty-two per cent. of fruits, eleven per cent. being blackberries, eight per cent. cherries, one per cent. currants and five per cent. grapes. The fragments of grain eaten by the brown thrush will amount to four per cent. of the food of the family, and ants compose eight per cent. Lepidoptera, Diptera and Coleoptera are eaten in about equal ratios, the first forming thirteen, the second eleven and the third twelve per cent. of the entire food. Carabidæ amount to five per cent., June-beetles to four per cent., wireworms to two per cent. and snout-beetles to two per cent. Hemiptera stand at three per cent., about two-thirds of them predaceous, and Orthoptera at four per cent. Five per cent. of the food was recognized as cutworms. More briefly, thirty parts of the food consist of injurious insects, including the larva of Bibio, and eight parts of beneficial species, while twenty-six parts consist of edible fruits; or we may say that injurious insects compose about one-third, the edible fruits about one-fourth and the beneficial insects about one-twelfth of the food of the family, the remaining elements being of neutral value.

TABLE OF THE FOOD OF THRUSHES IN APRIL AND MAY.

	Robin	Catbird	Brown Thrush	Wood Thrush	Hermit Thrush	Alice Thrush	Swainson's Thrush
No. of specimens examined	31	22	28	8	18	10	6
KINDS OF FOOD.	Ratio in which each element of food was found.						
1. MOLLUSCA	.01	....	....	†	....	.05	....
2. INSECTA	.93	.83	.65	.84	.87	.95	.98
Hymenoptera	.03	.22	.05	.20	.16	.47	.31
Ants	.03	.18	.05	.20	.13	.43	.28
Lepidoptera	.24	.14	.08	.21	.19	.15	.22
Noctuidæ	.09	.02	.04	.08	....	.02	....
Diptera	.12	.20	.03	.15	.01	.09	.07
Tipulidæ	.03	.19	....	.15	....	.08	.07
Bibionidæ	.04	....	....	....	....	....	....
Coleoptera	.43	.23	.38	.23	.30	.18	.30
Carabidæ	.11	.09	.07	.09	.11	.01	.05
Scarabæidæ	.19	.01	.24	.06	.06	.10	.06
Coprophagous	....	....	....	....	.05	.10	....
Phytophagous	.12	.01	.19	.02	.01	....	.06
Elateridæ	.04	†	.02	.06	.01	.02	†
Rhynchophora	.03	.05	.02	.02	.02	.03	.03
Chrysomelidæ	.01	.01	....	....	.02	.01	.02
Hemiptera	.04	†	.02	.01	.08	....	....
Predaceous	.03	†	.02	....	.06	....	....
Herbivorous	....	....	....	....	....	....	....
Orthoptera	.05	.04	.03	.03	.08	.03	....
3. ARACHNIDA	.01	.03	.02	.01	.04	†	.01
4. MYRIAPODA	.01	.07	.04	.13	.09	.02	.01
5. FRUITS AND SEEDS	.03	.07	....	....	....	....	....
6. FRAGMENTS OF GRAIN	....	....	.29	....	....	....	....

TABLE OF FOOD OF FAMILY TURDIDÆ. (THE THRUSHES.)

	Robin	Catbird	Brown Thrush	Wood Thrush	Hermit Thrush	Alice Thrush	Swainson's Thrush	Mocking-bird	TOTAL	Corrected average
No. of specimens examined	114	70	64	22	21	11	11	2	315	..
KINDS OF FOOD.	Ratio in which each element of food was found.									
1. MOLLUSCA	....	....	....	....	....	.05	....	...	...	...
2. INSECTA	.65	.43	.51	.72	.84	.93	.62	...	...	.61
Hymenoptera	.04	.13	.08	.15	.16	.47	.19	...	...	.09
Ants	.04	.12	.07	.15	.13	.43	.17	...	...	.08
Lepidoptera	.17	.07	.07	.13	.18	.15	.12	...	...	.13
Noctuidæ	.08	.01	.01	.04	....	.04	....	...	...	.05
Diptera	.17	.05	.01	.12	.04	.09	.04	...	...	.11
Tipulidæ	.01	.05	....	.12	....	.08	.04	...	...	.03
Bibionidæ	.15	....	....	....	....	....	....	...	...	.07
Coleoptera	.18	.12	.25	.18	.29	.18	....	...	...	.12
Carabidæ	.06	.04	.06	.06	.14	.01	.05	...	...	.05
Melolonthidæ	.03	.02	10	.03	.01	....	.03	...	...	.04
Elateridæ	.02	....	02	.03	.01	.02	†	...	...	.02
Rhynchophora	.02	.01	.02	.03	.03	.10	....	...	...	.02
Chrysomelidæ	....	.01	†	....	.02	.01	....	...	...	...
Hemiptera	.03	.02	.04	.01	.10	....	.02	...	...	.03
Predaceous	.02	.01	.01	.01	.07	....	.01	...	...	.02
Herbivorous	....	.01	.01	....	....	....	.01	...	...	...
Orthoptera	.04	.03	.04	.06	.07	.03	.01	...	...	.04
3. ARACHNIDA	.01	.02	.01	.01	.04	....	.02	...	...	.01
4. MYRIAPODA	....	.03	.03	.07	.12	.02	.01	...	...	.02
5. FRUITS	.34	.51	.24	.19	....	....	.35	...	...	.32
Strawberries	....	.01	....	....	....	....	....	...	...	...
Blackberries	.09	.24	.17	....	....	....	†	...	...	.11
Cherries	.11	.12	.03	....	....	....	.06	...	...	.08
Currants	.02	.01	....	....	....	....	....	...	...	.01
Grapes	.07	.03	†	....	....	....	.27	...	...	.05
6. FRAGMENTS OF GRAIN	....	....	.21	....	....	....	....	...	...	.04

Family SAXICOLIDÆ. (The Stonechats.)

Sialia sialis, L. The Bluebird.

This beautiful and beloved bird, endeared to the student of nature by every particular of its plumage, song and way of life, is also one of the most popular of all birds with farmers and gardeners. Living under the eyes of men from the first yielding days of the later winter until the year grows chill and dark with the retreat of autumn, it has been praised most warmly for its tireless service of man by those who knew it best. A cursory observation of its feeding habits will strongly support the general impression of its usefulness. Most frequently it takes a short, quick flight to the ground from a fence-post, or a low branch of a tree, and, after a moment's pause, returns to its perch with a caterpillar or a grasshopper or some other insect in its beak, which it devours at its leisure, repeating this operation so frequently that none can doubt its enormous destructiveness to insect life.

It is true that a little reflection will suggest that, as it evi-ently sees its prey before it leaves its perch, it must usually take only the most conspicuous and the most active insects, and that there is no security that these will be the most injurious—that they may not be, in fact, among the most beneficial; but this consideration does not seem to have made any impression, and the bluebird remains to this day substantially without reproach.

I have now examined carefully, with the microscope, the contents of one hundred and eight stomachs of this species, of which ten were taken in February, twenty-one in March, thirteen in April, nine in May, ten in June, nine in July, twelve in August, ten in September, two in October and twelve in December (in southern Illinois). I propose to present the data for each of these months; to summarize them for the year; to estimate the benefit and injury indicated to farm and garden, and to make a comparison of the food of this bird with that of the robin, and of the thrushes generally.

February.

The ten birds of this month were all shot at Normal, Ill., from the 24th to the 29th of the month, in the present year. These stomachs, with those obtained from Galena, in early March, represent the first food of the season.

The record opens with a bird shot on the 24th. Thirty per cent. of its food had been grass-eating cutworms, forty per cent. crickets (*Gryllus abbreviatus*), five per cent. Ichneumonidæ (*Arenetra nigrita* Cress.), and twenty-five per cent. the larvæ of the two-lined soldier-beetle (*Telephorus bilineatus*). Now, the ichneumons are doubtless parasitic, although about the habits of the genus Arenetra, I have at present but little specific information; and the soldier-beetles are reported by Professor Riley and others to be highly useful insects, noted especially for the destruction of the apple-worm and the eggs of grasshoppers.*

Taking the month together, we find that the most important elements of the food were cutworms and ichneumons—twenty-four per cent. of the former to twenty-two per cent. of the latter. The larvæ of the soldier-beetles amount to eight per cent., locusts (chiefly the young of *Tragocephala viridifasciata*) to nine per cent., Carabid beetles and their larvæ (including Amara and Anisodactylus) to five per cent., Pentatomidæ or soldier-bugs (chiefly *Euschistus servus*) to seven per cent., spiders to four per cent., and Iulidæ (thousand-legs) to three per cent. Other items are, two per cent. caterpillars of Arctians (*Callimorpha lecontei*), four per cent. crickets, and nine per cent. dung-beetles (*Aphodius fimetarius* and *A. inquinatus*). The ichneumons, Carabid beetles, soldier-bugs and spiders thus make up forty-six per cent. of beneficial insects, while the caterpillars and Orthoptera amount to but forty-one per cent. of injurious species. Or, if we drop the Pentatomidæ from the former category, on account of the supposed trifling injuries to vegetation done by some of them (hence often called "plant-bugs"), the figures will stand, beneficial insects thirty-nine, to forty-one injurious.

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*See 4th Rep. State Ent. Mo., p. 29, and Rep. U. S. Ent. Comm., 1877, p. 302.

March.

Twenty-one specimens were examined which had been shot in this month, in 1880, ranging from the 7th to the 31st. Seven of these were shot at Normal, nine at Heyworth (fifteen miles south) and five at Galena, in extreme northwestern Illinois. These latter differed from the central Illinois specimens chiefly in the presence of the dried and sometimes mouldy fruit of the sumach (*Rhus glabra*) in their stomachs, indicating a scarcity of desirable food at that early season. One of these, unfortunately for the record of the month, had stuffed itself with larvæ of Harpalus, which made ninety-three per cent. of its food.

Ichneumonidæ (Arenetra) appear again (four per cent.), for the last time during the season.

Harpalid beetles and their larvæ were unusually abundant, making up eleven per cent. of the food of the month. Among these Platynus, Evarthrus, Pterostichus, Amara, *Chlœnius tomentosus*, Agonoderus and Harpalus were recognized. The larvæ of soldier-beetles also occur, constituting four per cent. of the food, but do not appear again throughout the year. Four birds had eaten a predaceous bug (*Coriscus*, near *ferus*),* which is too minute to figure in the ratios; and four per cent. of the food was Pentatomidæ, of which only *Peribalus modestus* was recognizable. Sixteen of the twenty-one birds had eaten spiders, making five per cent. of the food. The beneficial insects thus amount to twenty-eight per cent. On the other hand, thirty-eight per cent. was caterpillars, chiefly Noctuidæ,† including *Callimorpha lecontei* and the army-worm (*Leucania unipuncta*); one per cent. was *Euryomia inda*, and twenty-one per cent. was Orthoptera (crickets and grasshoppers), the injurious species thus rising to sixty per cent. One bird had also eaten a minute curculio. Among neutral elements we enumerate Aphodii three per cent., Iulidæ three per cent., and sumach berries four per cent. Two birds had eaten ants, but in trivial quantity.

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*Kindly identified for me by Mr. Uhler.

†I have thus reported all smooth caterpillars in which the cervical and anal shields, common to most cutworms, were distinguished. A few such caterpillars are not Noctuids, but are equally injurious.

In order to determine the number of specimens which it is necessary to examine in each month, to reach reliable averages of benefit and injury, I divided my notes on twenty of the specimens for March, into two groups of ten each, so selected that all the localities and all parts of the month were equally represented in each group; and then averaged each ten separately and compared the averages. In the first group beneficial insects composed twenty-nine per cent. of the food, and injurious insects fifty-nine per cent.; in the second group beneficial insects composed twenty-seven per cent. of the food and injurious insects sixty-one per cent. The close correspondence of these averages shows that, on this question, ten specimens would have given as accurate information as twenty, and indicates that ten birds a month will usually afford a fair basis for an opinion.

April.

The food for April, as shown by the thirteen specimens of that month (from Normal, Evanston, Waukegan, and Elizabeth, in 1876 and 1880), was remarkable for the number of Aphodii (dung-beetles) it included; twenty-one per cent. of the food of the month was *Aphodius inquinatus*, nine per cent. *A. fimetarius*, and one per cent. undetermined Aphodii. This peculiarity is accounted for, in harmony with what has been said above respecting the feeding habits of the bluebird, by the fact that this is the month when the Aphodii fly most actively in the latitude of northern Illinois. Carabidæ now stand at eight per cent., including *Carabus palustris*, Pterostichus, Evarthrus, and other Pterostichi, Platynus, *Chlænius tomentosus*, *Anisodactylus rusticus*, *Amphasia interstitialis*, and Harpalus; four per cent. of Hemiptera includes Coriscus and *Hymenarcys nervosa*, while spiders rise to nine per cent. Caterpillars are twenty-one per cent. (seventeen per cent. Noctuids), June-beetles (Phyllophaga) two per cent., Curculionidæ one per cent., and grasshoppers (Tettigidea sp. and *Tettix ornata*) eight per cent.; a total of thirty-two per cent. of injurious insects against twenty-one per cent. of predaceous species. Among the neutral elements we find a sprinkling of ants (two per cent.), larvæ of a Tenebrionid (*Meracantha contracta**) four per cent., and thousand-legs (Iulidæ) one per cent. Long strips of grass, in pieces much too large to have been eaten by any of the insects present, were found in the stomachs of two of these birds, and also occurred during each of the three following months. I am in doubt whether these were taken as food; but, since I have found them in no other bird, and since a species which feeds so largely on cutworms and grasshoppers may have acquired the power of digesting the very considerable quantities of grass contained in the intestines of these insects, I have thought it best to include them in the percentages of food. It is probable, however, that they were swallowed accidentally with insects taken from the ground.

It will be noticed that the excess of Coleoptera in April is largely compensated by the diminished quantities of Orthoptera and caterpillars.

May.

In this month nine birds were taken, from six localities in central and northern Illinois, in 1876–80. The Lepidoptera, Coleoptera and Orthoptera return to about their normal ratios, but spiders rise to the excessive figure of twenty-one per cent. This ratio is, however, partly misleading, as, although six of the nine birds had eaten spiders, yet eleven per cent. is due to a single bird, which had eaten nothing else. In such a case a larger number of specimens is required to restore the balance, so violently disturbed. Two birds of this month had eaten moths, and five had eaten cutworms. The averages stand fifty-five per cent. of moths, caterpillars, June-beetles, curculios and Orthoptera, opposed to thirty-five per cent. of Carabidæ, soldier-bugs and spiders. The Carabidæ include *Cratacanthus dubius*, *Agonoderus comma*, Anisodactylus, and Harpalus. Other details may be obtained from the table at the close of this paper.

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*For the determination of this species and most of the other larvæ which have been identified specifically, I am under obligations to Professor Riley.

June.

In June, ten birds—one from Mt. Carroll, the others from Normal—had taken a somewhat unusual diet. The ratio of spiders (eighteen per cent.) falls little short of that for May, but an examination of the notes shows that here, too, a single bird had eaten nothing else. Ants rise suddenly from two per cent. in May, to twenty per cent in June, taken by six of the birds. Most of these, however, were of the winged forms, and their number is evidently due to the same cause which rendered the Aphodii so abundant in April. Three of the birds of June proved, to my surprise, to have eaten raspberries, and one gooseberries—these fruits amounting to eight per cent. of the food of the month. No cutworms were recognized in June, but measuring-worms (Phalænidæ) replaced them, composing six per cent. of the food. While all the cutworms found in any month whose food was at all distinguishable had eaten nothing but grass—or endogenous foliage, more accurately speaking—several of these Phalænidæ had been feeding on net-veined leaves. The Harpalinæ (six per cent.) include Evarthrus sp., *Pterostichus lucublandus* and *Anisodactylus baltimorensis*. June-beetles (Phyllophaga) had been eaten by one bird, and a Melanotus, a curculio, and a long-horn beetle (*Tetraopes tetraophthalmus*), each by one. Pentatomidæ reach five per cent., chiefly *Hymenarcys nervosa*, and Orthoptera fall to three per cent. The excess of ants is therefore taken, like the excess of Aphodii, from the caterpillars and grasshoppers.

The averages of beneficial and injurious species stand thirty per cent. to twenty-six per cent., respectively. Regarding ants, I find such conflict of opinion among good authorities, that I am not able to give them a definite place on either side of the line. The injury to fruits is probably too insignificant to be taken into account, except as evidence that the species is not strictly insectivorous, even in midsummer.

July.

The nine birds of this month were all shot in central Illinois, during four successive years. Besides the return of the percentages of Hymenoptera, Coleoptera, Lepidoptera and Arachnida to about their usual figure, we notice the large ratios of June-beetles (twelve per cent.) and Orthoptera (twenty-seven per cent.). The latter includes seven per cent. of *Udeopsylla nigra*, a large cricket-like locust. We find also a trace of raspberries in the food of two individuals. The caterpillars eaten by these birds were unrecognizable, except those from a single stomach, which Professor Riley has identified as *Nephelodes violans*, Guen. The record of benefit and injury is now more favorable to the species,—sixty-seven per cent. of injurious insects, and only fourteen per cent. beneficial, the latter Carabidæ and spiders.

August.

Twelve specimens were obtained in August, at Normal, three early in the month and the others on the 29th and 30th. The bluebirds were at this time most abundant in meadows and pastures; and the contents of their stomachs indicate that the chief business of the month was the pursuit of locusts, crickets and grasshoppers, moths and caterpillars. The Orthoptera eaten by these birds amounted to fifty-eight per cent. of their food, and the Lepidoptera to twenty-seven per cent. About half of the former were Gryllidæ (Gryllus and Nemobius), and the remaining half were equally Locustidæ and Acrididæ (*Xiphidium fasciatum* and *ensifer*, *Caloptenus femur-rubrum* and *bivittata*, and *Œdipoda sordida*). Half of the Lepidoptera were unrecognizable moths, and the remainder caterpillars—five per cent. being Noctuidæ. Ants were about one per cent. of the food, Coleoptera only five per cent. (including three per cent. Harpalidæ), Pentatomidæ (*Cœnus delius*) one per cent. and spiders six per cent. A few wild cherries and elderberries were the only fruits taken. The beneficial elements thus amounted to nine or ten per cent. of the food and the injurious elements to about eighty-five per cent.

September.

All but one of the ten specimens upon which the account of the September food is based were shot at Normal, and all but two on the 29th of the month. The chief peculiarity of the month is the almost total disappearance of Coleoptera, which were represented only by a few small Harpalids and a single minute Atænius. The Lepidoptera rise to thirty-seven per cent., chiefly through the abundance of the larvæ of *Prodenia lineatella*, Harvey. The Orthoptera make nearly half the food, the species differing from those of the preceding month mainly in the greater number of red-legged grasshoppers. Spiders were only two per cent. of the food; and some unknown wild fruits formed seven per cent. It will be seen that a striking change in the food of this species attends that increase of the Orthoptera in numbers and activity which occurs in the late summer and early autumnal months, these insects being almost entirely substituted for Coleoptera, Hemiptera and Arachnida. The Coleoptera of the six preceding months averaged twenty-seven per cent. of the food, while this order amounts to but three per cent. in August and September. The Orthoptera of the foregoing months averaged but fourteen per cent., while those of the two months in question rise to fifty-four per cent. It is evident from the foregoing that Orthoptera and smooth caterpillars are the favorite autumnal food of this bird, and as the first of these remain abundant until frost, it is not likely that the food of October is much less favorable to the bird than that of September. The two specimens taken in the former month were well filled with winged ants.

December.

To learn the food of the bluebird in midwinter, I went to extreme southern Illinois in December, 1879, and shot a number of specimens, some from the heavy forests in the bottoms of the Ohio River, and others from the wooded and cultivated highlands in Pulaski county. The weather at this time was sometimes above and sometimes below freezing, and bluebirds were abundant and very much at home. The principal food of the twelve specimens examined consisted chiefly of various wild fruits (eighty-four per cent.), of which the berries of the mistletoe (*Phoradendron flavescens*) were the most abundant (fifty-eight per cent.). Grapes, the berries of sumach, scarlet thorn (Cratægus) and holly (*Ilex decidua*) were also found. Sixteen per cent. of the food was insects, of which the larger part (ten per cent.) was the larva of Harpalinæ,—eaten, however, by but two of the birds. Prominent among these was the larva figured and described by Professor Riley in the Report of the United States Entomological Commission for 1877, p. 290, and there doubtfully referred to *Harpalus herbivagus.* The remaining kinds were *Geotrupes blackburnii*, *Podisus spinosus*, a single spider, and one unknown caterpillar. Even in the dead of winter, therefore, this bird does not cease its warfare on our predaceous bugs and beetles.

Summary for the Year.

To these figures, giving the averages for all the months mentioned taken together (except October), I invite special attention. Being derived from a much larger number of specimens than any of the monthly averages, they are much less likely to be affected by accident or error. They give, furthermore, the basis for an estimate of the total effect of the bird, year after year; and from this we should be able to predict the probable effect of a destruction or diminution of the species.

Taking up first the injurious insects destroyed, we find that these include twenty-six per cent. of Lepidoptera, nearly two-thirds of which were recognized as *Noctuidæ*, three per cent. of leaf-chafers and twenty-one per cent. of Orthoptera—a total of fifty per cent. on this side of the account. On the other hand, the ichneumons amount to three per cent., the Carabidæ to seven per cent., soldier-beetles to one per cent., soldier-bugs to three per cent. and spiders to eight per cent.—a total of twenty-two per cent. of predaceous and parasitic forms. Other elements are ants four per cent., Diptera only a trace, Aphodii six per cent., Iulidæ one per cent. and vegetable food thirteen per cent. The edible fruits amount only to about one per cent. of the food of these one hundred and eight specimens. Comparing with the Turdidæ, we find that the bluebird is essentially a thrush in food. From the robin it differs principally in the larger number of Hymenoptera (seven to four) and Lepidoptera (twenty-six to seventeen), the lack of Diptera (robin seventeen per cent.), the excess of Aphodii (six to two), of Pentatomidæ (robin one per cent.), of Orthoptera (twenty-one to four) and of spiders (eight to a fraction); but especially in the matter of edible fruits (one to thirty-four). These differences are but little greater, however, than those among the thrushes themselves. Compared with the thrush family as a whole, its salient peculiarities are its neglect of Diptera and garden fruits and its preference for Lepidoptera, Orthoptera and spiders.

Economic Relations.

Mr. B. D. Walsh, the first State Entomologist of Illinois, reasoning from the comparative numbers of injurious and beneficial insects, concludes that a bird must be shown to eat at least thirty times as many injurious individuals as beneficial before it can be considered useful.*

According to this estimate, the bluebird does at least thirteen times as much harm as good; that is to say, the beneficial insects eaten would themselves have destroyed thirteen times as many injurious insects as the birds have eaten. This conclusion is so unexpected and astonishing that it certainly cannot pass without careful examination. In the first place we should bear in mind that nothing has yet been learned of the food of the young, and there is some reason for supposing that birds select the softer insects for their young. Whatever deficiency of credit may be due to this neglect of the food of the young is compensated in part, at least, by the fact that the number of caterpillars eaten is doubtless overestimated in comparison with hard insects, as their flexible skins remain in the stomachs of birds longer than the hard structures of insects. This is exactly contrary to the usual supposition, but the frequent occurrence of the empty and twisted skins of cutworms in the stomachs of these birds, still recognizable as Noctuidæ when not even a fragment of a single head remains, is sufficient evidence that the hard parts break up

*"Birds vs. Insects." Practical Entomologist, Vol. II., pp. 44-47.

and disappear before these delicate but yielding skins. Secondly, while our knowledge of the food of Arctians, cutworms and grasshoppers is sufficiently definite and full to enable us to predict with certainty exactly what would happen if those eaten by bluebirds were allowed to live and multiply, we have not the same complete and certain knowledge of the food habits of the different genera of Ichneumonidæ, the ground-beetles, the soldier-bugs and soldier-beetles.

One hundred bluebirds, at thirty insects each day, would eat in eight months about 670,000 insects. If this number of birds were destroyed, the result would be the preservation, on the area supervised by them, of about 70,000 moths and caterpillars (80,000 of them cutworms), 12,000 leaf-chafers, 10,000 curculios and 65,000 crickets, locusts and grasshoppers. How this frightful horde of marauders would busy itself if left undisturbed, no one can doubt. It would eat grass and clover and corn and cabbage, inflicting an immense injury itself, and leaving a progeny which would multiply that injury indefinitely. On the other hand, would the 160,000 predaceous beetles and bugs, spiders and ichneumons either prevent or compensate these injuries? I do not believe that we can say positively whether they would or not.

In a discussion of the natural checks upon the cutworms Professor Riley, in his First Report as State Entomologist of Missouri, mentions two species of Ichneumon that parasitize the larva, credits the spined soldier-bug and the Carabid larva, *Calosoma calidum*, with its destruction, and says that some kinds of spiders are known to prey upon it.

From the Report of the United States Entomological Commission for 1877, we learn that the grasshopper is preyed upon at one or the other stage by Agonoderus, Harpalus, Amara and other Carabids; by soldier-beetles, soldier-bugs and spiders; and that certain Ichneumonidæ parasitize the egg. It seems *probable*, therefore, that the beneficial insects eaten by bluebirds include the special enemies of the cutworms and grasshoppers it destroys; but he who knows best the small number of reliable observations upon which our general statements of the food of predaceous insects rest, will have the most hesitation in trusting them without reserve.

I would also call attention to the fact that we do not yet know that the normal rate of increase among these carnivorous and parasitic insects is not sufficient to keep their numbers full to the limit of their food supply, and to furnish also a *surplus* for destruction by birds. Just as a tree puts forth more leaves than it needs, and sets more fruit than it can possibly mature, as an offset to the constant, normal depredations of insects, so there is much reason to suppose that our insect friends have become adjusted to this steady drain on their numbers.

TABLE OF THE FOOD OF THE BLUEBIRD. (*Sialia sialis*, L.)

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL.	Ratio of each element to whole of food.
Number of specimens......	...	10	21	13	9	10	9	12	10	2	...	12	108	
KINDS OF FOOD.	Number of specimens, and ratio in which each element of food was found.													
I. INSECTS..........	...	10 .92	21 .88	13 .88	9 .76	9 .71	9 .89	12 .91	10 .91	...	...	5 .16	98	.78
1. *Hymenoptera*..........	...	7 .22	5 .04	5 .02	3 .02	7 .21	6 .04	4 .01	4 .04	...	...	...	41	.07
Formicidæ.............	...	...	2 †	5 .02	3 .02	6 .20	6 .04	4 .01	4 .04	...	...	...	30	.04
Ichneumonidæ.........	...	6 .22	2 .04	...	...	...	...	...	...	...	...	...	8	.03
2. *Lepidoptera*...........	...	8 .28	20 .38	9 .21	7 .39	5 .13	7 .27	7 .27	7 .37	...	...	1 .02	71	.26
Arctiinæ...............	...	1 .02	4 .04	...	...	...	...	...	...	...	...	...	5	.01
Noctuidæ...............	...	6 .24	11 .39	5 .17	3 .19	...	1 .10	2 .05	4 .14	...	...	...	32	.12
Phalænidæ.....	...	...	...	...	...	2 .06	...	...	...	...	...	...	2	.01
3. *Diptera*.............	...	1 †	1 .01	1 †	...	1 †	...	...	...	...	...	...	4	....
4. *Coleoptera*............	...	9 .22	16 .19	13 .51	8 .18	7 .28	10 .26	7 .05	4 .02	...	...	4 .13	78	.20
Carabidæ...............	...	6 .05	16 .10	10 .08	5 .12	3 .06	4 .09	6 .03	2 .01	...	...	2 .10	54	.07
Dytiscidæ.......	...	...	...	...	...	1 .01	...	...	...	...	...	...	1	....
Staphylinidæ..........	...	...	...	1 †	...	...	...	...	...	...	...	...	1	....
Histeridæ............	...	...	1 †	1 †	...	...	...	...	...	...	...	...	2	....
Byrrhidæ.............	...	...	...	1 .01	...	...	...	...	...	...	...	...	1	....
Scarabæidæ...........	...	3 .09	4 .04	10 .33	2 .05	5 .12	3 .14	3 .02	1 †	...	...	1 .03	32	.09
Aphodius............	...	3 .09	2 .03	10 .31	1 .03	4 .04	...	...	1 †	...	...	...	21	.06
Geotrupes...........	...	...	...	...	...	...	...	...	...	...	...	1 .03	1	....
Phyllophaga.........	...	...	...	1 .02	1 .02	1 .08	2 .12	...	...	...	...	...	5	.03
Euryomia...........	...	...	1 .01	...	...	...	...	...	...	...	...	...	1	...
Elateridæ.............	...	...	1 †	...	...	1 .01	...	...	...	...	...	...	2	....
Tenebrionidæ..........	...	...	...	1 .04	...	...	...	...	...	...	...	...	1	....

TABLE OF THE FOOD OF THE BLUEBIRD. (*Sialia sialis*, L.)—Concluded.

	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	TOTAL	Ratio of each element to whole of food.
Number of specimens	...	10	21	13	9	10	9	12	10	2	...	12	108	
KINDS OF FOOD.	Number of specimens, and ratio in which each element of food was found.													
Telephorus	...	3 .08	2 .04	...	...	...	...	...	...	...	...	...	5	.01
Curculionidæ	...	1 †	1 †	3 .01	2 .01	1 .01	3 .01	...	...	...	...	...	11	....
Cerambycidæ	...	...	...	...	...	1 .01	1 .02	...	...	...	...	...	2	....
Tetraopes	...	...	...	...	...	1 .01	1 .02	...	...	...	...	...	2	....
5. *Hemiptera*	...	4 .07	10 .04	7 .04	2 .02	3 .05	2 .05	1 .01	1 †	...	...	1 .01	31	.04
Coriscus	...	...	4 †	1 .01	...	...	...	...	...	...	...	...	5	....
Alydus	...	...	...	...	...	...	1 .04	...	...	...	...	...	1	....
Pentatomidæ	...	3 .07	7 .04	4 .02	2 .02	3 .05	1 .01	1 .01	...	...	...	1 .01	22	.03
6. *Orthoptera*	...	7 .13	13 .21	5 .08	6 .13	2 .03	5 .27	12 .57	9 .48	...	...	...	59	.21
Gryllidæ	...	1 .04	2 .03	...	1 .02	...	1 .01	6 .28	2 .11	...	...	...	13	.05
Locustidæ	...	...	...	...	...	...	1 .07	4 .15	1 .02	...	...	...	6	.03
Acrididæ	...	6 .09	11 .18	5 .08	5 .11	2 .03	5 .19	4 .14	6 .33	...	...	...	44	.13
II. ARACHNIDA	...	6 .04	16 .05	9 .09	6 .21	5 .18	2 .05	6 .06	3 .02	...	...	1 †	54	.08
III. IULIDÆ	...	6 .04	8 .03	2 .01	1 .01	...	2 .02	...	...	...	...	...	19	.01
IV. VEGETABLE FOOD	...	...	3 .04	4 .02	3 .02	5 .11	6 .04	3 .03	1 .07	...	...	12 .84	37	.13
	Percentages for each month													Ratios.
Beneficial elements	...	46	28	21	35	*38	14	10	03	...	...	11	...	22
Injurious elements	...	41	60	23	55	26	67	80	85	...	...	02	...	49
Neutral elements	...	13	12	56	10	34	19	10	12	...	...	87	...	29

* Includes 8 per cent. fruit.

NOTES UPON THE FOOD OF PREDACEOUS BEETLES.*

BY F. M. WEBSTER.

Pliny thought it nothing to the credit of the philosophers of his day, that while they were disputing about the number of heroes by the name of Hercules, and the site of the sepulcher of Bacchus, they should not have been able to decide whether or not the queen bee possessed a sting.[1]

While the problem of the bee sting has long been decided, and heroes by the name of Hercules have ceased to trouble the minds of men, there are problems of vital importance regarding the habits of the insects which, during the greater portion of the year, we meet daily in abundance, that still remain unsolved.

The most important as well as the most abundant of these insects are the beetles.

While found in almost every conceivable situation, while our naturalists count the species in their cabinets by the thousands, it would be difficult to point out a single species, the food habits of which we *fully* understand, when both the larvæ and imago state are taken under consideration.

True, we have a sort of ritual laid down by entomologists, based upon the fact that certain species have been known to feed upon certain substances, but this can no more be considered as proof that nothing else enters into their natural diet, than does the meat of which we may partake at dinner prove us to be strictly carnivorous, or the bread or fruit, that we are exclusively vegetarians.

An illustration of this double diet of beetles is found in the case of the European *Silpha opaca* Linn., the larva of which has been known to feed to an injurious extent upon the leaves of the beet and mangel-wurzel.[2]

But one of the most fortunate in getting the benefit of our ignorance is the family Carabidæ, to utter a word against which is almost considered a sacrilege.

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*Although this paper does not belong with the studies made at the Laboratory, but is based entirely upon the author's personal observations, it is included with this series, with his permission, because it relates to the same subject. These observations precede, in point of time, those of the following paper.—S. A. F.

[1]Pliny, Hist. Nat., l, xi, c, 17.
[2]Curtis, "Farm Insects," p. 388.

But, true to the adage "murder will out," occasionally a species is found feeding upon vegetation with a voracity that would do credit to a Chrysomelid. Of these in Europe, besides the *Zabrus gibbus* in both stages, some of the Pterostichi, Amara, Omophron, and *Calathus latus* Westw., are said to injure grain by eating off the young shoots or destroying the seed.[3]

Two species of Bembidium (*lampos* and *monticola*) have been destructive to the forests of upper Austria.[4]

Broscus cephalotes attacks the growing grain, and *Aristus bucephalus* devours the seeds of grass.[5]

In our own country the *Omophron labiatum* Fab. injures the shoots of young corn in the Southern States.

Harpalus caliginosus Fab. is suspected of feeding upon grain in stack in Maryland, and also of eating timothy seeds from the heads.[6]

E. T. Dale, of Jasper, Mo., forwarded to the editors of the American Entomologist specimens of an insect found by him feeding upon the seeds of a plant unknown to him. Upon examination they proved to be *H. caliginosus*.[7]

According to Mr. Mather, of Marshalltown, Iowa, the larvæ of some species of Harpalus are destructive to his evergreens, he having found them eating off the roots.[8]

The foregoing is a synopsis of all facts relating to the vegetable-feeding Carabidæ, so far as known to the author of this paper. A number of years ago the writer commenced the study of the food of beetles, correctly judging from what was then known, that either naturalists were in error in their suppositions or else that innocent insects were wrongly accused. And he is free to confess his partiality to the former theory as being the most correct. But after several years of study and observation, I have found to my astonishment not only the species accused but others also of this family feeding largely upon vegetable substances, both useful and noxious. Among my

[3]Report U. S. Agr. Dept., 1868, pp. 79–80.
[4]Deutsche Entomologische Zeitschrift, 1879, p. 417.
[5]Westwood's Introduction, I., p. 61.
[6]Report U. S. Agr. Dept., 1868, p. 80.
[7]Am. Ent., Vol. I., p. 80.
[8]Am. Ent., Vol. III., p. 26.

earliest observations on this subject I noted the abundance of Carabidæ about the shocks of wheat in a field where a violent wind storm had blown down a large number of sheaves, under which, upon their being replaced, large numbers of *Harpalus caliginosus*, *pennsylvanicus* and *herbivagus*, *Pterostichus lucublandus* and *Anisodactylus baltimorensis* were observed.

The wheat was drawn in and threshed directly from the field, and a large percentage of the kernels were badly eaten. Previous to the threshing, in another field, a specimen of *H. pennsylvanicus* was captured with a partially eaten grain of wheat in its mandibles. The eaten grains of the threshed wheat seemed to agree with the fragments found in the jaws of the beetle, and as no other destructive agencies were noted, the facts seemed to suggest that the damage was done by the before-mentioned Carabidæ. A few days after, *H. pennsylvanicus* was found eating the now fully ripe seeds from a head of upright timothy grass, and was observed to detach them from the glumes. The same species has since been seen feeding largely upon ragweed, *Ambrosia artemisiæfolia* Linn., during September, the seeds apparently being the favorite part. A short time after it was found upon timothy grass it was observed eating the seeds of prairie grass, *Panicum crus-galli* L.; and the same day another individual was found devouring an *Ips fasciatus* Oliv., one of the Nitidulidæ, thus proving its carnivorous propensities also. *H. caliginosus* is likewise found eating the seeds of *Ambrosia artemisiæfolia*.

H. herbivagus feeds largely upon the tender shoots of grass during March, cutting them off just below the surface; but later it selects the tender blades and the discolored parts usually found under boards, etc.

Amara angustata Say is found quite abundantly upon the heads of June grass, *Poa pratensis* L. But the most voracious Carabid enemy of this grass is the *Anisodactylus sericeus* Harris.

Early in June, 1878, vast numbers of these beetles were noted upon the heads of this grass; in fact, spots several yards in area were literally covered with them. After patient watching—for they are very timid—the proof was conclusive that the unripe seeds were what they were after, and not microscopic insects as was at first supposed.

The insect is not only cunning, drawing up its legs and dropping to the ground upon the least disturbance, after the manner of a Chrysomelid, but also shows considerable ingenuity. It grasps the lower extremity of the glume tightly in its mandibles, then relaxing slightly, passes upward and again tightens its grasp,—a series of movements which finally force the seed, which is now of the consistency of cream, out at the apex. This it at once proceeds to devour with an appetite which reminds one quite forcibly of a tramp who has been obliged to earn his dinner in advance. Later in the season it is found feeding in the same manner upon the seeds of *Agrostis vulgaris* Witt. Specimens of *Anisodactylus baltimorensis* Say were observed feeding upon the marrow and fatty matter clinging to the tibia of some dead animal, probably that of an ox. Attention is called to this as being in perfect accord with microscopic observations reported by Mr. Forbes in the following paper, upon another specimen found upon grass a few months later.

Calathus gregarius Say may be found abundantly upon the heads of timothy grass during the early mornings of the first of July. Of the genus Platynus only a single observation has been obtained, and this was during the latter part of June of the present year, when two specimens of *P. cupripennis* Say were seen harassing a half-grown cricket, which they had already disabled. The carnivorous habits of beetles are often as difficult to discover as their vegetarian. Usually they are not at all in favor of public dinners, and, like beasts or birds of prey, prefer to drag their victims to some secluded nook to devour them; hence, if the observer gets any insight into this part of their domestic affairs he must take them by surprise. In this manner a *Staphylinus cinnamopterus* Grav. was surprised while in the act of devouring an *Anomoglossus pusillus* Say, having first, to guard against its escape, eaten off four of its legs.

In another instance a *Dyschirius globulosus* Say was observed to spring upon a small salmon-colored maggot-like larva, and, after disabling it, to start off to select a proper place to devour it. After the lapse of several minutes, it returned to drag its victim under a small clod of dirt and leisurely feast upon it.

After the same manner a *Bradycellus rupestris* Say was surprised under a stone while eating a small white thread-like worm.

Another family of beetles whose hitherto almost untarnished reputation it seems to have fallen to my lot to soil is the Coccinellidæ. With the exception of *Epilachna borealis* Fab. the larva of which feeds upon the vines of the gourd family,[9] these insects in our country have been considered strictly carnivorous, although several European species are known to deviate from this rule.

This season, specimens of *Megilla maculata* DeG. have been taken while feeding upon the pollen of the dandelion, *Taraxacum dens-leonis*, and it is not at all improbable that the pollen of other plants also forms a part of their diet, as they are rather common upon the blossoms of plants and fruits.

No accurate estimation of the value of the Coleoptera could be obtained without including the Telephoridæ. Besides *Chauliognathus pennsylvanicus* Först., which has been found feeding upon the larvæ of the *Conotrachelus nenuphar* Hbst.,[10] and *Telephorus bilineatus* Say, which is such a powerful auxiliary in checking the ravages of the western locust,[11] *Podabrus tomentosus* Say has been observed feeding upon the cottonwood gall-lice, *Pemphigus populivenæ* Fitch, and the *P. populicaulis* Fitch. These beetles sometimes place themselves at the opening of the gall, occasionally as many as four together, and catch the mature lice as they attempt an egress, and sometimes plunge their flat head and thorax into the cavity and draw forth and devour large and small indiscriminately. During the latter part of June and the first of July these beetles are very abundant, not only upon trees affected by gall-lice, but upon other plants also.

[9]Am. Ent., Vol. II., p. 373.
[10]Am. Ent., Vol. I., pp. 35 and 51.
[11]Report U. S. Ent. Comm., Vol. I., p.302.

NOTES ON INSECTIVOROUS COLEOPTERA

BY S. A. FORBES.

MOUTH STRUCTURES OF CARABIDÆ.

In studying the food of birds, I found it necessary to construct a key to the genera of the Carabidæ, based primarily upon the mouth structures, and prepared for this purpose a large number of slides of the mouth parts of Illinois species. In studying these, two characters were noted, which proved to be of considerable service for classification. The first of these is the frequent obliteration of the suture between the mentum and the gula (called the "gular suture", by Dr. LeConte, in his Classification, Pt. I., pp. X., XIII., 14, 15 and 16), the mentum being, in such cases, connate with the gula. This is true of Blechrus, although in Trechicus and Metabletus of the same group the suture is distinct. The mentum is again connate in many species, at least, of several genera of Dapti and Eurytrichi; viz., Geopinus, Anisodactylus, Xestonotus, Spongopus and Amphasia; but is not connate in Nothopus, Piosoma, Discoderes or Anisotarsus. This character was noticed nowhere else except in *Amara angustata*, which differs in this respect from all the other Amaræ in the Laboratory collection. This species is also peculiar in the very great development of the muscular ridges on the upper surface of the mentum. In the Lebiæ this mental suture is distinct in the middle but obsolete at the ends.

The second character referred to is found in the stipes of the maxilla. This body is covered with three plates—an outer, closely connected with the palpus, a lower, from which the two lobes of the maxilla spring, and an upper plate, which is applied to the under surface of the mandible. The last of these usually presents, in the Harpalidæ, a more or less prominent angle at about the anterior third of the outer margin, although this margin is sometimes regularly curved. In two genera, Agonoderus and Stenolophus, this plate is produced forward and outward beyond the articulation with the palpus (which thus seems to spring from beneath it), forming an oblique lamina with a rounded outer angle and an acute tip. This character seems to distinguish Stenolophus from Harpalus, as far as I have been able to compare the species.

Food of the Carabidæ.

The large numbers of Carabidæ eaten by several of our common birds make it important that the somewhat doubtful food habits of this family should be more thoroughly studied; and I have undertaken the microscopic examination of the contents of stomachs and intestines as one branch of this investigation. The facts thus obtainable perhaps cannot give us a complete idea of the food of these insects, but should probably be taken in connection with field observations, as these beetles are said frequently only to suck the juices of their prey, rejecting the solid parts; and where this has been done the fact will be only obscurely indicated by the contents of the alimentary canal. Where this contained an abundance of fatty chyme with no solid tissues to fix its source, I have sometimes doubtfully inferred such an event; but usually liquid food will escape detection.

The results of the examinations thus far made are so interesting that I am impelled to give the method I have found most successful and convenient, with the hope that others may turn their attention to the same subject. The dissection should be made as soon as possible after the beetle is taken,—within a few days at farthest,—as the more unstable elements of the food are apparently soon changed, even in strong alcohol. If the beetle is as large as *Megilla maculata*, the elytra and wings may be cut off and then, while the insect is held between the thumb and finger of the left hand, the edges of the abdomen may be carefully trimmed away with a pair of fine scissors (those with curved blades are best) leaving the soft dorsal covering attached only at the base and tip. If one blade of the scissors be now carefully passed under this dorsal integument, it may be cut across and reflected (with the forceps and a mounted needle) forwards and backwards and cut entirely away. It will next be necessary to unroof the meso- and meta-thoracic segments, which usually contain at least a part of the crop. It will not be difficult to cut through the crusts of these segments at each side with the scissors-points. The terga may then be removed, as before, with forceps and needle. The specimen (if not too large) should now be transferred to a watch crystal, covered with glycerine and placed on the stage of the microscope; (a dissecting microscope is a convenience, but not indispensable). With mounted needles the reproductive organs, urinary tubes, etc., can be pushed out of the way, when the crop, stomach and intestine will be seen, variously arranged according to the family and genus. It is an easy matter to cut the alimentary canal loose at either end and to remove it from the body, placing it upon a slide in a shallow cell, with glycerine enough to mount the contents. Here the superfluous structures should be picked away, as far as possible, and then the stomach and intestines may be torn open with needles, and their contents spread out and picked in pieces upon the slide. After the removal of the remnants, the cell may be covered and the contents studied with any power necessary. The cover should, of course, be finally cemented down and the slide preserved for verification and repeated examination.

Galerita janus.—A specimen of this insect, taken at Bloomington, in September, contained but little food. All that was recognized consisted of insect fragments, one of which was a spinose tibia. It was impossible even to tell the order of the insect eaten.

Loxopeza atriventris.—Four specimens of this species were examined, three of which were taken in June and the other in September. The alimentary canal of the first was entirely empty. The second, sent me by Mr. A. S. McBride, from DeKalb county, had eaten immense numbers of minute, oval bi-nucleate cells, which, believing them to be spores of fungi, I referred to Prof. T. J. Burrill, of the Illinois Industrial University. He reported them to be "spores of Sphæronemei, probably Phoma"—a fungus which forms small, black specks on dead wood, stems of weeds, etc. A third specimen from the same source had eaten some undetermined, insect and about equal quantities of three elements; viz., the above spores of Phoma, pollen and the anthers of grass (doubtless blue-grass upon which the insect was taken). A few clavate bodies were also noticed, consisting of a single row of nucleated cells,—evidently the acrospores of some fungus. A September specimen was taken at Normal. Its crop was distended with an oily liquid, but contained no other visible food except a few acrospores of a fungus. This specimen had evidently been feeding upon animal food of some sort.

Calathus gregarius.—Three individuals of this species were examined, all caught on blue-grass in blossom, by Mr. Webster, of Waterman, and Mr. McBride, of Freeland. The crop and œsophagus of the first were distended with a brown mass which proved to be wholly made up of the pollen and fragments of the anthers of grass. A second specimen contained a smaller amount of pollen and anthers of blue-grass, with minute fragments of a black and sparsely hairy insect. An antenna proved that it was a larva—probably a young caterpillar. The third contained traces of a similar larva and the fragments of the cornea of a perfect insect—evidently a remnant of some former repast.

Anisodactylus baltimorensis.—The single specimen of this species had not recently taken food. The stomach was empty; but in the intestine was a large amount of chyme which possibly indicated liquid animal food. A specimen of *A. rusticus* gave only similar negative results.

Anisodactylus sericeus.—A specimen taken in June showed fragments of anthers and pollen of grass, with other vegetable tissues, apparently derived from the seeds of grass. A small insect had also been eaten, as shown by particles much too few and minute for determination. A second specimen had taken precisely similar food—the insect here being represented by a few facets of the cornea.

Amara angustata.—One of this species, likewise taken in June, had also fed on vegetation, as indicated by a few particles of parenchyma too far digested for recognition; but fully nine-tenths of its food consisted of spherical eggs, in different stages of development, many of them easily recognizable as the eggs of mites. The most advanced embryos had six legs and a pair of large palpi; and, by the shape of the abdomen and the position of the legs, recalled the larvæ of the spinning mites (Tetranychi).

Harpalus pennsylvanicus De G.—A specimen of this species taken running in the road, at Normal, August 31st, had the alimentary canal well filled with vegetable tissues, some of which were evidently derived from the ovules and roots of grass. Among these were the tips of an ovule with the styles unbroken and the tip of a rootlet with the root-cap entire. A single mite was found, and a few acrospores of fungi. This beetle was infested by a large number of intestinal parasites of the genus Gregarina. A second specimen had eaten similar vegetable food. Here a piece of the epidermis of a rootlet, still covered with trichomes, was noted, as well as several root-tips and fragments from the growing tips of grass. Pieces of the epidermis of grass with their peculiar zigzag cell boundaries, confirmed these determinations. A detached stigma of a grass floret and a few stylospores completed the food. A third specimen, taken at Normal on the 5th of September, contained some vegetable tissues with spiral cells, the mandible and maxilla of an ant and vast numbers of minute, spherical corpuscles, which Professor Burrill regarded as forms of bacteria such as occur on stagnant water. This beetle had apparently skimmed this minute vegetation from the surface of some pool. The fourth specimen of this species, received in September, from Mr. Webster, who collected it from the blossoms of ragweed, I found to have eaten large quantities of vegetable tissue, the fragments of which showed branched bundles of spiral ducts with parenchyma between. These were evidently the bracts or other floral organs of the ragweed.

Harpalus caliginosus.—A single individual, running free upon the ground, had gorged itself with plant and animal food,—apparently about three times as much of the former as of the latter. In the crop were a few hairs of a caterpillar and much half-digested muscle, with spores of fungi, a little epidermis of some graminaceous plant and a few pollen grains of Compositæ. In the stomach was a great deal of chyme, with fragments of the wings and tarsi of some minute dipter, more pollen of Compositæ and some vegetable parenchyma, apparently derived from unripe seeds of grass. In the ileum and colon these last mentioned tissues predominated, although the latter contained also a large quantity of pollen of Compositæ indistinguishable from that of ragweed (Ambrosia). Here were also found two feet of a larva,—possibly of the previously mentioned caterpillar. It is worthy of notice that these Harpali were full of eggs, of which there were about six in each abdomen. The crop of the second specimen, taken at Normal, in September, was distended with a brown, oily fluid, containing no recognizable material. In the intestine was a small mite and considerable vegetable parenchyma, apparently derived from some young seeds or ovules of plants. A little parallel-veined vegetable tissue was also seen, evidently derived from grass.

Harpalus herbivagus.—A specimen of this beetle, taken by Mr. McBride, in July, was filled with cryptogamic vegetation which had the form of a dense mat of slender branching tubes enclosing many spherical cells. This, Professor Burrill, to whom one of the slides of this material was referred, regarded as a fleshy or cartilaginous fungus with Palmella cells, although he thought that it might have been derived from a lichen. A second specimen, obtained by Mr. Webster, in March, had evidently been feeding on the young shoots of grass.

Cratacanthus dubius.—One of this species, taken at Normal, in August, contained no apparent food except a few spores of fungi. In the stomach were great numbers of Gregarina, apparently of the same species as those found in *Harpalus pennsylvanicus.* In the colon, especially, scores of these parasites in the "resting state" formed considerable masses which half filled the intestines.

Evarthrus colossus.—One of this species, taken in September, had eaten a brown beetle of medium size, the fragments of which filled the whole alimentary canal. From the general appearance of these, from the tips of one anterior and one middle tibia and from a maxillary palpus, it was inferred that this beetle was one of the Scarabæidæ. A fragment of a mandible showing a ridged masticatory surface, made it likely that it was a vegetable feeder. There was no trace of vegetable food in this Evarthrus. Another specimen, taken at Normal, in September, had eaten a large Coleopterous larva and two minute, indeterminable insects. Traces of confervoid Algæ were also discovered in the intestine.

Pterostichus sayi.—A specimen of this species, taken at Normal, in September, was full of the remains of an unrecognized hairy insect with two tarsal claws.

Pterostichus lucublandus.—This specimen, taken likewise at Normal, in September, contained a multitude of fragments of some Hymenopterous insect, including a maxillary palpus and a labrum nearly entire, with pieces of the legs and tarsi. This beetle had also eaten a small mite and a few acrospores of fungi.

Chlænius tomentosus.—One of this species, taken at Normal, in September, contained traces of insect food not otherwise determined, and a nematoid parasite.

Chlænius diffinis.—A specimen of this species, taken under a log, near Normal, in September, contained traces of some crustaceous insect, with pieces of vegetable tissue (apparently wood) penetrated by the mycelium of a fungus. Large vegetable fragments were also seen, which Professor Burrill determined as pieces of a large, fleshy fungus. The stomach likewise contained acrospores of Dematiei.

Bradycellus dichrous.—A specimen, taken at Bloomington, in September, had eaten insect food not otherwise determinable.

Twenty-eight specimens of Carabidæ, representing seventeen species, are here reported. It will be seen that twenty-one specimens, belonging to fifteen species, had eaten animal food, and that twenty specimens, belonging to eleven species, had eaten vegetation of some sort. I estimated as carefully as possible the relative amounts of these two kinds of food in the alimentary canal of each insect, and from these data concluded that about half the food of these twenty-eight specimens consisted of vegetation, and that one-third of it consisted certainly of insects,—the remainder being made up of doubtful animal matter. About one-third of the vegetable food had been derived from cryptogamic plants and another third from the different structures of grasses, Compositæ and other miscellaneous vegetation making up the remainder. Considering the fact, however, that the commonest species were found feeding upon vegetation far the most generally, it is likely that, taking the Carabidæ as a group, not more than one-third or one-fourth of their average food consists of animal matter.

Food of Podabrus.

The contents of three stomachs of *Podabrus tomentosus* were examined; and all these had eaten only the spores of Phoma mentioned under Loxopeza. The specimens were all sent me in July, by Mr. A. S. McBride, of Freeland, Ill.

Food of Coccinellidæ.

Coccinella novem-notata.—Two specimens which were taken at Normal, in August, were examined, agreeing very closely in their food, each having eaten various spores of fungi (about ninety per cent.) and plant-lice (ten per cent.). Among the fungus spores, Professor Burrill, to whom they were submitted, recognized spores of *Ustilago and Helminthosporium*; and a few lichen spores were also noticed.

Brachyacantha ursina.—The stomach of one individual of this species contained only a few fungus spores.*

Hippodamia convergens.—A specimen, captured in August, at Normal, had eaten great quantities of fungus spores, which composed about three-fourths of its food. Fragments of a mite and a plant-louse and a little pollen of Compositæ were also found. In a second specimen, taken in September, the remains of a myriapod belonging to the family Geophilidæ, acrospores of a fungus, the pol-

*I have assured myself that none of the fungi found in the alimentary canals of these beetles were entophytes.

len of Compositæ and the remains of a plant-louse were the only elements noticed.

Megilla maculata.—Three specimens of this species were dissected,—one received from Mr. Webster in May, one from Mr. McBride in July, and one taken at Normal in September. The specimen from Mr. Webster was captured on the flowers of dandelions. Its entire alimentary canal was closely packed with hexagonal, spinose pollen cells, doubtless taken from that plant. A second had eaten the anthers and pollen of grass with a few spores of Myxogastres.* The third specimen contained pollen and fungus spores in about equal quantities. While these Coccinellidæ had made good their usual reputation as enemies of plant-lice, it should be noticed that these constituted only about ten per cent. of their food.

If these specimens of the various families of predaceous beetles are fair examples of their class, the above facts imply that the individual carnivorous insect is much less valuable than has usually been supposed, while predaceous insects as a class are much more beneficial. If these species are predaceous, as a rule, not more than from one-fourth to one-third of the time, the injury done by the destruction of one of them is very much less than if they were, as is usually supposed, almost wholly carnivorous. But, on the other hand, if they can live on the soft parts of plants when animal food becomes scarce, their numbers will be maintained at a far higher figure than would be possible if they were dependent upon animal food alone. Preferring animal food to vegetable, as they doubtless do when equally obtainable, they operate as a much more effective check on the undue increase of other insects than if their number were at all times strictly limited by the numbers of their food species. We should remember, in this connection, that we cannot ordinarily expect of any predaceous animal that it will do more than to eliminate the excess of the species it preys upon, keeping their numbers down within certain constant limits. As a prudent sovereign finds it worth while to maintain a much larger

*Burrill.

fighting force than is necessary to the ordinary administration of his government, in order that he may have always a reserve of power with which to meet aspiring rebellion, so it is to the general advantage that carnivorous insects should abound in larger numbers than could find sustenance in the ordinary surplus of insect reproduction. They will then be prepared to concentrate an overwhelming attack upon any group of insects which becomes suddenly superabundant. It is evidently impossible, however, that this *reserve* of predaceous species should be maintained unless they could be supported, at least in part, upon food derived from other sources than the bodies of living animals.