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EFFECTIVENESS IN NATURE OF THE SO-CALLED PROTECTIVE ADAPTATIONS IN THE ANIMAL KINGDOM, CHIEFLY AS ILLUSTRATED BY THE FOOD HABITS OF NEARCTIC BIRDS

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ERRATA

Page 56. In the table Identifications of Lepidoptera, the middle column is a relic from a set of calculations of the percentages of identifications among all insects. The appended figures are to be substituted as representing the percentages of identifications among all Lepidoptera. In explanation of the third column in this table, it may be said that it differs from others given further on in the work by omission of figures for families not represented among the food identifications.

Percentage of identifications among all Lepidoptera
2.6992
.0270
.0270
.8060
.0919
.2055
.0108
.0270
.0108
.0108
.4706
.0324
.9412
.0378
.6383
6.1015
.0216
.3678
.3570
.1568
.8438
11.4458
25.3306
.0487
.0054
.3191
.0054
.0108
.2218
.6112
.7248
68.5670
1.2279
3.5376

Page 86. The figure 1 before the decimal in the entry for the family Diopsidae should be deleted.

Pages 102-105. Insert the word "aquatic" after the word "all" in the heading for the middle column on each of these pages, with the exception of that at the bottom of page 105.

EFFECTIVENESS IN NATURE OF THE SO-CALLED PROTECTIVE ADAPTATIONS IN THE ANIMAL KINGDOM, CHIEFLY AS ILLUSTRATED BY THE FOOD HABITS OF NEARCTIC BIRDS

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INTRODUCTION

In a previous paper[1] the writer set forth reasons for believing that the results of experimental tests of the effectiveness of the so-called protective adaptations in protecting animals from their enemies are not trustworthy indications of what occurs under natural conditions. In the present contribution he proposes to show just what insects and other animals are actually preyed upon by wild birds of the United States, Canada, and Alaska, giving also incidental notes on other enemies. This evidence reflecting food habits under natural conditions goes far to show how little the alleged protective devices have to do with choice of food by vertebrates.

Judging from the literature of the subject since 1912, the contentions of the article on the experimental study of the food habits of animals seem to have been generally admitted, or at least regarded as too well supported to be lightly attacked. Only one essay has been seen by the writer, that seems in any way a reply, namely an account of "Experiments and Observations Bearing on the Explanation of Form and Colouring,"[2] by C. F. M. Swynnerton, who refers to my criticism of the experimental method as "rather over-vigorous." The vigor of the criticism is admitted but in view of the absurdity of the arguments against which it was directed, it can hardly be considered

[1] The experimental method of testing the efficiency of warning and cryptic coloration in protecting animals from their enemies. Proc. Acad. Nat. Sci. Philadelphia, June 1912, pp. 281-364 (Sept. 6, 1912).

[2] Journ. Linn. Soc., Zool., vol. 33, pp. 203-385, London, June 30, 1919.

excessive. Undeniably selectionists have been absurd in their disquisitions on adaptations; for instance "eye-spots" on a butterfly's wings are to direct the attack of enemies to a nonvital spot, while "eye-spots" on a caterpillar are "terrifying" and prevent even a touch where merely a touch would be fatal; in numerous species of birds the male is colored red and black or orange and black, characteristics that selectionists say have been developed by sexual selection as an attraction to the opposite sex, yet the females of these birds are supposed to be repelled by the same colors in possible insect prey; red insects are said to be warningly, red fruits invitingly colored, and so on. A popular foible of similar type is that of sportsmen who hold up to admiration the marvelous protective coloration of game birds, and in the next breath complain of severe depredations on these birds by "vermin."

But this is digressing and the writer is glad to acknowledge that if all of the experimenters had been as critical of their methods and conclusions as Mr. Swynnerton, the tone of his former paper would have been quite different. For instance Mr. Swynnerton carried on more experiments than any of the authors reviewed in the previous communication, before he, according to his own confession, learned how to experiment. This in itself confirms the writer's charges that the experiments he reviewed were both inadequate and misinterpreted. It may further be stated that the principal conclusions Mr. Swynnerton draws from his experiments and observations would have been agreed to in advance by anyone experienced in the study of bird food. Thus he concludes that birds show preferences among the food items available to them, and that predatory animals of various groups show more or less agreement in preferences. From his general experience with birds he decides also that "Unless through sheer impossible hardness, size, etc., there is practically no such thing as 'inedibility,'"[1] and he appreciates that a group of insects, limited in numbers as are butterflies, will not be taken by insectivorous birds out of proportion to their abundance as compared to all insects available.

These things did not require experimental test for they are corroborated in every thorough report on the natural feeding habits of birds. What can not be admitted, however, is that preferences of birds learned by feeding them upon some certain group of insects to an extent far greater than the birds ever prey upon them in nature, reflect normal feeding habits, nor that there is evidence of intensive enough feeding by discriminating enemies upon any group of insects

[1] A brief preliminary statement of a few of the results of five years' special testing of the theories of mimicry. Proc. Ent. Soc. Lond., 1915, pp. xxxii-xliii.

to meet the requirements of the selection theories. We further can not admit what the experimenters imply, namely, that the analyses of the stomach contents of birds fail to reveal the approximate numbers present of certain insects (such as butterflies) which they believe are eaten to a considerable extent. This point will be discussed later.

So much for what has happened between the previous paper and the present, which as stated, will be devoted chiefly to an exposition of the animal food of nearctic birds, with special reference to the so-called protective adaptations.

PROTECTIVE ADAPTATIONS

The characteristics of animals that are usually classed as protective adaptations include resemblance to generalities or details of the environment, whether through color or other modification of the animal itself or utilization by it of materials from the environment for concealment, the possession of protective bristles, spines, hard integuments, stings, poisonous bites, and the like, and nauseous or irritating odors or tastes. There are animals with actually poisonous properties among many of the phyla including species with poison glands and special organs for using the poison in offense or defense, among Coelenterata, Echinodermata, Arachnida, Insecta, and Pisces; others with poison glands connected with the mouth organs among worms, spiders, other arachnids, mites, myriapods, chilopods, insects, fishes, and reptiles; animals with unarmed poison glands among coelenterates, echinoderms, myriapods, insects, mollusks, amphibians; and others poisonous in a variety of ways so that practically all phyla are represented. The colors of the animals possessing dangerous qualities in many cases are said to be warning in nature, and the colors of animals which resemble them but lack the disagreeable qualities are termed mimetic. The subject of protective adaptations has very largely become one of coloration especially as associated with the qualities of animals from the supposed point of view of possible predators.

A statement of the various classes of color adaptations is here quoted from Prof. E. B. Poulton, the leading advocate of the view that these adaptations are really protective and that they have been developed by natural selection.

Protective and Aggressive Resemblance.—By far the most widespread use of colour is to assist an animal in escaping from its enemies or in capturing its prey; the former is *Protective*, the latter *Aggressive*. It is probable that these were the first uses to which non-significant colours were put. The resemblances are of various kinds; the commonest cases are those of simple concealment. The animal passes undetected by resembling some common object which is of

no interest to its enemies or prey respectively, or by harmonising with the general effect of its surroundings; the former is *Special,* the latter *General Resemblance,* and both may be *Protective* or *Aggressive.* Among the most interesting *Special Aggressive Resemblances* are the cases of *Alluring Colouring,* in which the animal, or some part of it, resembles an object which is attractive to its prey.[1]

Protective and Aggressive Mimicry.—Mimicry is in reality a very important section of *Special Resemblance.* The animal gains advantage by a superficial resemblance to some other, and generally very different, species which is well known and dreaded because of some unpleasant quality, such as a sting or an offensive taste or smell, &c., or it may even be protected from the animal it resembles: this is *Protective Mimicry.* When, however, the animal resembles another so as to be able to injure the latter or some other form which accompanies it or is not afraid of it, the *Mimicry* is *Aggressive.*[2]

Warning Colours.—When an animal possesses an unpleasant attribute, it is often to its advantage to advertise the fact as publicly as possible. In this way it escapes a great deal of experimental "tasting." The conspicuous patterns and strongly contrasted colours which serve as the signal of danger or inedibility are known as *Warning Colours.* In other cases such colours or markings enable individuals of the same species easily to follow those in front to a place of safety, or assist them in keeping together when safety depends upon numbers. It is these *Warning Colours* which are nearly always the objects of *Protective Mimicry.*[3]

Following is a copy of Poulton's table[4] classifying color adaptations:

I. *Apatetic colours.*— Colours resembling some part of the environment or the appearance of another species.		II. *Sematic colours.*—Warning and signalling colours.	III. *Epigamic colours.*—Colours displayed in courtship.
A. *Cryptic colours.*—Protective and Aggressive Resemblances.	B. *Pseudosematic colours.*—False warning and signalling colours.		
1. *Procryptic colours.*—Protective Resemblances.	1. *Pseudaposematic colours.*—Protective Mimicry.	1. *Aposematic colours.*—Warning colours.	
2. *Anticryptic colours.*—Aggressive Resemblances.	2. *Pseudepisematic colours.*—Aggressive Mimicry and Alluring Colouration.	2. *Episematic colours.*—Recognition Markings.	

Having presented the foregoing outline of protective color and other adaptations, references to them in succeeding pages will be made without further explanation of the terms involved.

[1] The colours of animals, pages 19-20, 1890.
[2] Idem, p. 20. [3] Idem, p. 21. [4] Idem, p. 338.

ANIMALS EATEN BY NEARCTIC BIRDS

Data Cited and How Obtained

The main body of data used herein consists of the records of animals identified in the contents of the stomachs of about 80,000 nearctic birds examined in the United States Biological Survey since 1885. These stomachs represent a wide range of species of all of the families of birds occurring in the region; the birds were collected at all seasons and in practically all parts of nearctic America. While not evenly distributed in any of these senses, the collection is very satisfactory for the purpose in hand, and yields a mass of precise information on bird food that far surpasses anything of the kind available elsewhere.

A word about the methods of investigating bird food may be desirable. The gizzards of birds, together with the gullets or crops when they contain food, are received chiefly from persons collecting birds for some other scientific purpose, although in some cases they are especially obtained to throw light on the relations of birds to some crop, or useful or injurious animal. They are preserved usually with formalin in the field and in alcohol after receipt at the laboratory. Contents of a stomach being examined are removed either wet or dry as best fits the particular case and transferred to watch glasses or small white blotters for sorting and identification of the material under compound binocular dissecting microscopes. A great deal of the analysis is done at a magnification of 8 diameters but special study of difficult subjects is continued when necessary under higher powers.

At this point it may be well to comment on the popular misconception that anything found in a bird's stomach necessarily is ground up and in all but unrecognizable state. As a matter of fact the reverse is true. Most birds swallow their food whole; consequently in any collection of birds a certain proportion will have swallowed some food items just before death. These things often are in perfect condition; they may be, and sometimes are, used for cabinet specimens. The nearly or quite whole objects usually furnish clues to the fragmentary material, and in the great majority of cases it is possible to sort out completely all components of the food. It is the exception when the finely ground food remains defy separation and identification. Determinations are carried as far as practicable; each member of the staff of analysts is a specialist in some line and they cooperate freely; specimens defying their combined efforts, if in fair or better condition, are submitted to advanced investigators elsewhere. The records

quoted in the following pages include more or less of the handiwork of practically every prominent American systematic zoologist of the period. Nevertheless everything is not identified, far from it; expert assistance has not been available in some cases when needed, too far digested residues sometimes occur, and rarely we find also well-preserved but puzzling objects that indefinitely defy classification.

These, however, are but minor flaws in the system; the groundwork of our faith in the results of stomach analysis is the law of averages. Given good distribution geographically and seasonally, which necessarily follows from miscellaneous collecting carried on for so many years, the reliability of results varies directly with the number of stomachs. The collection (80,000) here reported upon is believed sufficient to furnish fairly dependable data, although additions are made almost daily to the list of animals identified from bird stomachs.

The total number of identifications of animals from these stomachs, counting those of whatever degree, once for each time identified irrespective of the number of individual specimens concerned, is 237,399.[1]

It was impracticable to compute the total number of individual animals concerned for the reason that these were not counted in all cases. Moreover this figure would not have been especially useful in the absence of estimates for comparison of the actual animal population of significant areas. In casting about for a standard which would afford some idea of the frequency of occurrence of animals of various groups, the estimated number of species therein proved to be the only one available for the whole range of the animal kingdom. That the number of species in taxonomic groups bears a general relation to the number of individuals can not be questioned. It is easy to point out exceptions, but remember we can only deal with this problem in an approximate way, and it goes without saying that on the average a group more numerous in individuals will have developed more species than one less numerous. The correspondence is not exact, but it is sufficient to give a fair working idea of the position of the various groups in the scale of frequency of occurrence, the

[1] The tabulation necessary to yield this figure was an immense one (covering nearly a thousand typewritten pages) and has been found, it is not surprising, to contain some errors. These are so small, however, that rectification of them would not cause changes of more than a fraction of one per cent in any part of the results, except in the table for Coleoptera, pp. 65-67. Hence they do not invalidate the figures at all for the purpose here used of showing in a general way the tendencies exhibited by our birds in their choice of animal food.

very standard we wish for comparison with frequency of identification in the stomachs of collected wild birds. The general correlation of these factors to be noted in the tables presented in subsequent pages increases confidence in the value of the method.[1]

Identifications of Animal Food

To illustrate the way in which data was assembled, that for the phyla may be given in rather more detail than is planned for the balance of the report. The figures for number of species in the various phyla are compiled from various estimates[2] of this nature; the facts that these are not strictly up-to-date nor anything like exact are of no consequence in a field where only approximations may be hoped for.

The subjoined table shows the estimates used for the number of described species in each phylum and the percentage that figure bears to the total number of animals known.

Phyla of Animals and the Number and Percentage of Species in Each

Phylum	Estimated number of species known	Percentage of species in this phylum among the whole number
Protozoa	8,000	1.4272
Porifera	2,500	.4460
Coelenterata	4,500	.8028
Platyhelminthes	5,000	.8920
Nemathelminthes	1,500	.2676
Trochelminthes	500	.0892
Molluscoida	1,700	.3032
Echinodermata	4,000	.7136
Annulata	4,000	.7136
Arthropoda	418,250	74.6188
Mollusca	61,000	10.8828
Chordata	49,565	8.8427
Totals	560,515	99.9995

[1] Here may be mentioned the law demonstrated by Olaf Arrhenius (Journ. Ecol., vol. 9, no. 1, p. 99, Sept., 1921) that among plants "The number of species increases continuously as the area increases." Since as a rule the number of individuals also increases with the area, the parallelism between the number of individuals and that of species is further confirmed.

[2] Pratt, H. S., On the number of known species of animals. Science, vol. 35, pp. 467-468, March 22, 1912.

Henshaw, H. W., Number of species of living vertebrates. Science, vol. 36, pp. 317-318, Sept. 6, 1912.

Handlirsch, A., Die fossilen Insekten, pp. 1182-1188, 1908.

Classifying the 237,399 identifications of the animal food of nearctic birds and calculating the percentage of the determinations, by phyla, we reach the results shown in the next table, the percentage of species in each phylum among the whole number of known species being repeated for ease in comparison.

Identifications of Animal Food by Phyla

Phylum	Number of identifications	Percentage of identifications among those of all animals	Percentage of species in this phylum among the whole number of animal species known
Protozoa	12	.0050	1.4272
Porifera	2	.0008	.4460
Coelenterata	122	.0514	.8028
Nemathelminthes	24	.0101	.2676
Molluscoida	134	.0564	.3032
Echinodermata	125	.0526	.7136
Annulata	1,131	.4764	.7136
Arthropoda	210,752	88.7751	74.6188
Mollusca	11,771	4.9583	10.8828
Chordata	13,326	5.6133	8.8427

Without going into details, it is apparent that the percentage of identifications preserves very well a relative ratio to that of the number of species and presumably, therefore, to the abundance of individuals in the phyla. What variations there are seem obviously due to differences in the availability to birds of the differing types of animals.

Taking up the phyla in order, we begin with the

PROTOZOA (ONE-CELLED ANIMALS)

Protective adaptations.—Judging from what is asserted about other phyla, phosphorescence and the possession of bright colors in some groups and of silicious or calcareous, often tuberculate or spinose, tests or shells or of exoskeletons formed of foreign bodies in others, are characters that would be deemed of protective significance in Protozoa.

Bird enemies.—Protozoa are too small to engage the attention of birds, those found in stomachs being Foraminifera strained from water or mud, or picked up as gravel by ducks. It is probable also that protozoa are consumed, along with the stems and leaves of aquatic plants upon which they often are abundant, by wild ducks

which feed upon such vegetation. Stomach analysis, however, has not been directed toward the recognition of such minute material.

Number of identifications, 12; percentage of identifications among those of all animals, .0050; percentage of species in this phylum among the whole number of animal species known, 1.4272.

Other enemies.[1]—Protozoa are the prey of others of their kind—of bacteria, of rotifers, of flatworms, of amphipods and other small crustacea, and of mollusks; they are eaten also by the young of numerous species of fishes, by the adults of specialized forms (menhaden, gizzard shad), and by the larvae of batrachians.

Discussion.—Protozoa, because of their minute size and general inaccessibility to birds, would not be expected to enter largely into the food of this class. The forms eaten by birds are among the best "protected" protozoa, but the possession of shells can hardly be considered as an adaptation for protection from enemies in the case of animals so small as to be easily devoured by almost any carnivorous animals encountering them and which exist in such enormous numbers that vast areas of sea bottom are covered with remains of their shells. In this case as in many others, numbers are so large and reproduction so great that the inroads of all enemies are fully discounted. Losses to predatory enemies are only a fraction of the total death rate.

PORIFERA (SPONGES)

Many sponges are pervaded by calcareous or silicious spicules which may render them more or less undesirable as food for predatory animals. Some are brightly colored and some phosphorescent. "Sponges do not appear to be edible by Fishes or even the higher Crustaceans or Molluscs. Countless lower animal forms, however, burrow in their substance, if not for food, at least for shelter, and the interior of a sponge is frequently found to be teeming with small Crustaceans, Annelids, Molluscs and other Invertebrates."[2]

Sponges have been identified from only 2 stomachs of nearctic birds (Canada goose and lesser scaup) and from their low degree of accessibility to birds, not many cases of feeding upon them would be expected.

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[1] Entries under this head for the various groups treated are intended as suggestive rather than as exhaustive. A list of papers from which much of this information has been gleaned forms the special bibliography on pp. 145-201. Notes on the food of reptiles, amphibians, and mammals are mostly from analyses of stomach contents in the Biological Survey.

[2] Parker, T. J., and Haswell, W. A., A text-book of zoology, vol. I, p. 126, 1910.

Number of identifications, 2; percentage of identifications among those of all animals, .0008; percentage of species in this phylum among the whole number of animal species known, .8028.

Discussion.—Information at hand seems to indicate that sponges are used very little as food by other animals; sea-urchins, marine worms, amphipods, and mollusks, however, are recorded as predators. Fresh water sponges are eaten to some extent by fishes. Whether this is credited to their "protective adaptations" is of little moment as the fact remains that sponges do not multiply excessively nor overrun the earth as forms that lack enemies are in theory supposed to do.

Sponges have bright and varied colors and one case of mimicry has been pointed out.[1] If it be true as apparent from observations thus far, that they have few or no enemies, natural selection can not be advanced as an explanation of their color phenomena. If sponges without enemies have adaptations of the same character as other groups with numerous enemies, it would seem evident that selection by predatory animals has no necessary connection with the adaptations.

COELENTERATA (HYDRAS, JELLYFISHES, SEA-ANEMONES)

Protective adaptations.—Some coelenterates have a chitinous cuticle, others have a calcareous skeleton, and many of them have nematocysts or stinging cells. Numbers of them are brilliantly colored or phosphorescent but it must be noted also that many are transparent or nearly so, showing that possession of protective devices (as the nematocysts) is not always accompanied by the development of "warning colors."

Bird enemies.—The Coelenterata most often found in bird stomachs are the Hydrozoa (such as *Abietinaria*, *Sertularella*, and *Thuiaria*). They have been identified 113 times from the stomachs of 13 species of ducks, 2 of gulls, and one each of murre, murrelet, and shearwater. Sea-anemones (*Anthopleura*, *Aulactinia*) have been identified four times from stomachs of a scoter, an eider, an oyster-catcher, and a gull, Alcyonaria from two ducks, and coral from one.

Number of identifications, 122; percentage of identifications among those of all animals, .0514; percentage of species in this phylum among the whole number of animal species known, .8028.

Other enemies.—Hydroids are eaten by marine worms, by sea-urchins and sea-anemones, and also by fishes, as the cod, haddock,

[1] McIntosh, W. C., The coloration of marine animals. Ann. Mag. Nat. Hist. 7th ser., vol. 7, p. 223, Mar., 1901.

sand launce, lump sucker, cunner, scup, filefish, and flatfishes; ctenophores are eaten by the spiny dogfish, flatfishes, whiting, and cod; sea-anemones are eaten by cod,[1] haddock, tilefish, flatfishes, the sunfish *Mola,* spiny dogfish, whiting, and by the so-called jellyfishes and by whales. Holothurians and some fishes (*Scarus*) feed on corals.

McIntosh notes that the brightly colored jellyfishes "have precisely the same habits as the uncoloured and transparent," which raises doubt as to the validity of the selectionist interpretation of the facts. The brightly hued and the translucent forms are equally palatable to whales and other animals using jellyfishes as food. He adds with regard to sea-anemones that "the view that the gaudy colors . . . . act as a warning is not borne out by the eagerness with which the cod swallows the brightest, such as *Stomphia,* while the smaller flatfishes fill their stomachs with *Edwardsiae.*" (Ann. Mag. Nat. Hist. 7th ser., vol. 7, pp. 224-225, 1901.)

Discussion.—Coelenterates are another group of animals but slightly available to birds and seem to be taken in full proportion to the degree of availability. The nematocysts seem a futile defense against animals of the groups here mentioned as coelenterate enemies, and must be also in the case of the myriads of crustacea (possible enemies) all of which have a chitinous exterior and which moreover manipulate their food in the chelae before chewing it, a process that would result in the harmless discharge of the stinging cells. It is alleged that hermit crabs have a commensal relation with certain hydroids which grow upon the shells they inhabit and that they are protected from their enemies by the presence of the inedible stinging hydroids.[2] This is not the case where the bird enemies are concerned, as the sea ducks which are the principal bird enemies of hydroids, often swallow the hermit crab, shell, hydroids and all. Many of the examples identified from bird stomachs came from precisely this source. With respect to the practical aspect of the case, it would appear that in its shell retreat and its own strong claws the hermit crab has much more efficient defenses than the nettlelike hydroids. It seems more likely that the latter merely grow on mollusk shells as a convenient substratum. From the habit some hermit crabs have of frequently changing their abode, the advantage held by a "commensal" hydroid may be lost at any moment.

[1] McIntosh notes that sea-anemones are a valued bait for cod.

[2] Parker and Haswell, Zoology, vol. 1, p. 144, 1910.

PLATYHELMINTHES (FLATWORMS, FLUKES)

The majority of organisms of this phylum are parasitic and therefore not available to predatory animals. Perhaps some of the fresh-water planaria and the marine nemerteans have been found but not identified in the stomachs of shore birds, but so far we have no positive determination of a worm of this phylum as bird food. Forbes reports a small catfish (*Noturus*) feeding on fresh-water planaria. McIntosh says that marine planarians of both plainly and brightly colored forms are eaten by sea-anemones and fishes. Fresh-water planarians also are eaten by fishes. Stiles intimates that carp destroy large numbers of the liver fluke (*Fasciola hepatica*) in the cercaria stage.

NEMATHELMINTHES (THREADWORMS, ROUNDWORMS)

Again a vast number of worms of this phylum are parasites, abundantly so, in fact, of birds themselves. In order to reckon as food only those so taken, all nematodes other than Gordiidae have been kept out of the computations. The records for Gordiidae number 24, the percentage of these identifications among those of all animals is .0101, and the percentage of known species[1] of Nemathelminthes among all animals according to the estimates used in the present paper, .2676. The nematodes have a tough cuticle but no special defenses; nevertheless they certainly are not eaten out of proportion to their numbers, but considering availability to birds, they may possibly be eaten somewhat in ratio to the frequency with which they are encountered. They are eaten also by flatworms and by various fishes.

TROCHELMINTHES (ROTIFERS)

None of these have yet been identified as food of nearctic birds, though possibly rotifers taken in with foliage of aquatic plants may have been overlooked. Rotifers are eaten by the young of a number of fishes.

MOLLUSCOIDA (CORALLINES, LAMPSHELLS)

Protective adaptations.—Except for the shells of the brachiopods, and cuticular walls of some bryozoa, no special protective features have been developed by the Molluscoida.

Bird enemies.—Only three brachiopods have as yet been identified from the stomachs of nearctic birds—not a matter for surprise in

[1] An enormous number of Nematodes await description.

view of the small number and marine habitat of the species of these animals. The other Molluscoida that have been found in bird stomachs include Cyclostomata (having calcareous zooecia), Cheilostomata (with calcareous or chitinous zooecia), and Phylactolaemata. Large numbers of the statoblasts of the latter group, the fresh-water bryozoa, have been disclosed in the stomachs of wild ducks.

Number of identifications of Molluscoida, 134; percentage of identifications among those of all animals, .0564; percentage of species in this phylum among the whole number of animal species known, .3032.

Discussion.—Considering their low availability to birds, animals of this phylum probably are taken in due proportion. Fresh-water bryozoans have been recorded from stomachs of many species of fishes, and the marine forms from a smaller number. Marine bryozoans are preyed upon by worms, amphipods, decapods, and starfishes.

ECHINODERMATA (SEA-CUCUMBERS, SEA-URCHINS, STARFISHES)

Protective adaptations.—All of the echinoderms have a calcareous exoskeleton and in many the surface is beset with tubercles or spines. The starfishes and sea-urchins are armed also with pedicellariae or grasping organs, which in some cases in the latter group are said to be poisonous. Some sea-cucumbers have the "Cuvierian organs" which throw out long viscid filaments. Starfishes, especially the brittlestars and many crinoids, have the supposedly protective faculty of snapping off their arms or portions thereof. The colors of echinoderms are often conspicuous and in certain cases have been termed warning.

Bird enemies.—Starfishes have been identified 28 times in the stomachs of nearctic birds here reported upon; sea-urchins (*Strongylocentrus, Echinarachnius*) 92 times; and sea-cucumbers, 3 times. The birds (19 species) eating them were chiefly ducks collected in northern seas.

Number of identifications, 125; percentage of identifications among those of all animals, .0526; percentage of species in this phylum among the whole number of animal species known, .7136.

Other enemies.—Starfishes and sea-urchins prey upon one another, and are very commonly eaten by cod, haddock and other species of *Gadus,* by argentines, dragonets, rocklings, wolffishes, rays, sharks, tautog, scup, smelt, flatfishes, and others. Sea-cucumbers are less commonly taken by the same predators. Blue foxes on the Pribilof Islands feed on sea-urchins in winter. Sea-urchins and starfishes are consumed also by crabs, sea-anemones, and marine worms.

McIntosh comments interestingly on the enemies of echinoderms: "The colours of Echinoderms are often most conspicuously bright," but *Hippasterias*, which is brilliant orange-red, is eaten by gulls, cod, catfishes and by other starfishes. "The sand-stars (e. g. *Ophiura lacertosa*) are often tinted of a hue resembling their surroundings, yet they and the more brightly tinted forms are common in the stomachs of fishes and are eagerly devoured by gulls when stranded on the beach." "The brown and purple hues of sea-cucumbers may in some way subserve protection . . . . yet both they and the transparent forms are found in the stomachs of fishes." (Ann. Mag. Nat. Hist. 7th ser., vol. 7, pp. 225-226, 1901.)

Discussion.—Echinoderms have a number of protective devices but also it would appear, numerous and effective enemies. Birds prey upon this group to fully as large an extent as could be expected, considering the slight degree to which they come in contact with echinoderms.

It should be noted that while practically all starfishes and sea-urchins have similar protective adaptations, some are very gaudily, others modestly colored; in one case or the other, the natural selection theory as to the connection between special defenses and coloring is untenable. The sea-urchins with calcareous tests, abundant spines, and pedicellariae seem unusually well defended, but that this does not mean freedom from enemies is shown by the great fecundity of sea-urchins, individuals of some species, e. g., *Echinus esculentus*, yielding 20,000,000 eggs per season.

ANNULATA (WORMS)

Protective adaptations.—The chaetopods including the most common marine worms and the majority of earthworms have chitinous setae on all segments of the body. The earthworms are habitual burrowers, and some of both fresh- and salt-water annelids live in tubes. A few in each group are phosphorescent, and many of the marine worms are highly colored. A. R. Wallace says:[1] "Among the creatures which probably have warning colors as a sign of inedibility are . . . . those curious annelids the *Nereis* and the *Aphrodite* or sea-mouse."

It should be noted however that many of the brightly colored forms live in burrows or tubes, thus taking care not to advertise their "inedibility." Leeches sometimes have strongly contrasting color, as for example greenish with red and black spots.

[1] Darwinism, p. 266, 1896.

Bird enemies.—The identifications of Annulata from nearctic birds are: 690 for the Polychaeta, chiefly Nereidae, which have been found in the stomachs of more than 70 species of birds and in numbers up to 500 in a single stomach; 428 for the Oligochaeta or earthworms from 44 species of birds; and 11 of Hirudinea or leeches from 10 species. The robin (*Planesticus migratorius*) feeds habitually and voraciously upon earthworms and the woodcock (*Philohela minor*) makes about half of its diet of these annelids.

Number of identifications, 1131; percentage of identifications among those of all animals, .4764; percentage of species in this phylum among the whole number of animal species known, .7136.

Other enemies.—Studies that have been made of the food of fishes indicate that a very large number of marine fishes prey upon the Nereidae and other annelids. They are eaten also by other worms, starfishes, sea-urchins, sea-anemones, gastropods, and crabs. Freshwater oligochaetes form a steady contribution to the diet of the fishes of their environment. Earthworms are eaten by predacious beetles, by most batrachians, by some turtles, snakes and by various mammals including shrews, skunks, and the armadillo, but especially by the moles (*Parascalops breweri,* 26 per cent of the food; *Scalopus aquaticus,* 31 per cent; *Scapanus townsendi,* 40 per cent; *Condylura cristata,* 50 per cent.) Leeches are eaten by a variety of mammals, birds, reptiles, amphibians, fishes, crustaceans, snails, and insects.

Discussion.—Both of the annelids (*Nereis* and *Aphrodite*) Wallace mentions as being warningly colored are eaten by birds and fishes, *Nereis* frequently and in large numbers. Considering the aquatic habits of most of the annelids it would appear that they are taken by birds as often as could be expected. It is evident furthermore that they have numerous other predatory foes and that they probably contribute their full quota of food toward the dietary requirements of the animal kingdom.

ARTHROPODA (JOINTED ANIMALS)

As recorded previously in the table of phyla, the Arthropoda, including the exceedingly numerous class of insects, furnish, as would be expected, a very large preponderance of the animals eaten by birds.

Number of identifications, 210,752; percentage of identifications among those of all animals, 88.7551; percentage of species in this phylum among the whole number of animal species known, 74.6188. The disproportion of the percentage of capture to that of frequency reflects the relatively greater availability to birds of arthropods over the other phyla.

Since arthropods are by far the most important phylum of animals as bird food and since it is with reference to the included class of insects that the theories of protective adaptations have been most highly elaborated, it is desirable to subdivide the phylum for the purposes of the present discussion.

The tabulation below shows the number of identifications and their percentages for the four classes of Arthropoda that are available for food to nearctic birds.

Arthropoda

Class	Number of identifications	Percentage of identifications among those of all arthropods	Percentage of species in this class among the whole number of arthropod species known
Crustacea	6,086	2.8877	3.8254
Myriapoda	2,862	1.3530	.4781
Insecta	190,919	90.5891	91.8589
Arachnida	10,885	5.1648	3.8254

It is evident that the percentage of identifications for each class corresponds very well with the frequency of such animals as indicated by the number of species. The validity of such comparisons used throughout this paper thus receives further corroboration.

Crustacea (Crabs, Shrimps, Sowbugs)

Protective adaptations.—The exoskeleton of crustacea is either chitinous or much thickened or calcified. Several groups have bivalved carapaces in which the animal is nearly or entirely enclosed. The barnacles have a more complicated covering of calcareous plates, sometimes thick and hard. Most of the decapods have strong grasping forelegs, and have furthermore the faculty of snapping these off when properly stimulated. Some crustacea have burrowing habits (Hippidae) and others (hermit crabs) use the shells of univalves for shelter, while the terrestrial sowbugs roll themselves up into a ball when disturbed.

As to color, some of the smaller aquatic forms are translucent or transparent; the ostracods are said to assimilate with the general color of their environment, while some copepods and decapods are brilliantly colored. As to form, Mortensen says: "The typical cases of adaptation to life among algae are especially found among the Caprellids; they might be said to represent the Phasmids and Geometrid larvae, among marine animals" (p. 77). "*Idothea marina* and

related species . . . . bear a striking resemblance to the plants (especially *Zostera* leaves) on which they are found" (p. 78).[1]

"Many Crustacea," according to Parker and Haswell, "present instances of protective and aggressive characters, i. e., modifications in form, colour, etc., which serve to conceal them from their enemies or from their prey. Probably the most striking example is that of certain crabs (*Paramithrax*) which deliberately plant Sea-weeds, Sponges, Alcyonarians, Zoophytes, etc., all over the carapace, and are thus perfectly concealed except when in motion."[2]

Poulton expresses the same view in the following language: "Certain palatable animals make use of the Special Defence and Warning Colours of other forms. Thus, the common English hermit-crab, *Pagurus bernhardus,* commonly carries on its borrowed shell the conspicuous stinging sea-anemone *Sagartia parasitica;* while another English species, *Pagurus prideauxii,* inhabits a shell which is invariably clothed by the flattened *Adamsia palliata.* Two crabs (*Polydectus cupulifer* and *Melia tesselata*), from Mauritius, described by Mobius, invariably held a sea-anemone in each claw. Two other groups of animals, sponges and Ascidians, in addition to sea-anemones, are avoided by enemies of the Crustacea, and these are also employed by the latter. Thus the British hermit-crab *Pagurus cuanensis* is found in shells which are covered with a (generally) brightly-coloured sponge (*Suberites domuncula*). Mobius also describes a Mauritian hermit-crab (*Ascidiophilus caphyraeformis*) which lives in a case formed by an Ascidian."[3]

Bird enemies.—Most of the leading subdivisions of the Crustacea contribute to the food of birds, apparently about in proportion to their accessibility. The tabulation of numbers of species of Crustacea used for comparison with those of percentages of identifications was made from "A list of the Crustacea of New Jersey including the adjacent region or that of the Middle Atlantic States,"[4] the only check list available for any considerable area of our region.

The Anostraca (fairy shrimps) are locally eaten more extensively than indicated above and the fact is an illustration of the principle

[1] Mortensen, T. H., Observations on protective adaptations and habits, mainly in marine animals. Vidensk. Meddel. fra Dansk. naturh. For. Kjob., bd. 69, 1920.

[2] Zoology, vol. 1, p. 601, 1910.

[3] Poulton, E. B., Essays on evolution, pp. 356-357, 1908.

Thomas Scott records a copepod (*Acidicola rosea*) which lives within the branchial sac of an ascidian as having been eaten by a sole *Pleuronectes microcephalus.* (20th Ann. Rep. Fishery Bd. Scotland, p. 525, (1901) 1902.)

[4] Fowler, H. W., Ann. Rep. N. J. State Mus., pp. 463-598 (1911), 1912.

that in natural history as elsewhere sweeping statements based on partial or negative evidence are dangerous. No exception may be noted for one which claims that "enemies play no part in keeping down the numbers of *Artemia* (brine shrimps), or of *Ephydra* (alkali flies) in the larval stage."[1] Dr. Alexander Wetmore, of the Smithsonian Institution, who has had considerable experience about Great Salt Lake to which locality the quoted assertion relates, has pointed out[2] that *Artemia* and *Ephydra* are by no means free from enemies. Shovellers, lesser scaups, golden-eyes, green-winged teal, Wilson's and northern phalaropes, avocets, and black-necked stilts all feed extensively upon both of these animals. But for the fact that

Identifications of Crustacea

Group	Number of identifications	Percentage of identifications among those of all Crustacea	Percentage of species in this group among those of all Crustacea of the Middle Atlantic States
Unidentified	573	9.4150	...
Anostraca	28	.4601	1.3667
Cladocera	90	1.4788	4.1002
Ostracoda	207	3.4012	3.8724
Copepoda	13	.2136	18.2232
Cirripedia	401	6.5888	5.9225
Isopoda	385	6.3259	14.3508
Amphipoda	986	16.2010	9.3394
Cumacea	...	...	3.1891
Stomatopoda	...	...	.9112
Schizopoda	48	.7887	1.1389
Decapoda	3355	55.1260	37.5853

stomach analyses have not been made of other birds collected at the same place, it would undoubtedly be possible to add the names of a number of species to this list. Doctor Wetmore states that "the toll taken by birds from the brine shrimp and alkali fly larvae and pupae during the course of a season constitutes a mass of individuals almost beyond comprehension . . . . The immense numbers of these creatures . . . . must be attributed to the large number of offspring produced rather than to an absence of enemies." The number of records for the minute Cladocera is fully up to expectations. Among other items of this group the egg capsules or ephippia of *Daphnia* have been found in numerous stomachs of grebes and wild ducks, and in number up to 250 in a single stomach.

[1] Vorhies, Charles T., Notes on the fauna of Great Salt Lake. Amer. Nat., vol. 51, pp. 494-499, Aug., 1917.

[2] Amer. Nat., vol. 51, pp. 753-755, Dec., 1917.

The ostracods have been identified chiefly from the stomachs of 15 species of wild ducks, and no fewer than 1,200 have in two instances been taken from a single stomach. Most of the barnacles were found in the stomachs of 22 species of ducks, gulls, and shorebirds from northern waters. Amphipods were eaten by more than 80 species of birds, largely shorebirds, ducks, and other waterfowl; nearly 70 species of amphipods were identified and the number of individuals taken by single birds ran up as high as 2,500. The isopods were consumed by more than 75 species of birds, the land-forms or pillbugs alone by about half that many; the greatest number of individuals of terrestrial sowbugs found in a single stomach was 60, of aquatic forms, 256. In the Decapoda it may be of interest to note that 392 of the identifications were of shrimps, hundreds of individuals being present in some stomachs; 1,592 of Astacidae (crawfishes), the greatest number taken by one bird being 49; and 794 of crabs of various kinds. Among groups of crabs represented, there were the following numbers of captures, the figures in parentheses in each case denoting the largest number of individual crabs found in a single stomach: Sand crabs or sandbugs, Hippidae, 61 (14); stone crabs, Lithodidae, 90 (16); hermit crabs, Paguridae, 35 (40); mud crabs, Pilumnidae, 186 (36); swimming crabs, Portunidae, 39 (16); edible crabs, Cancridae, 41 (18); shore crabs, Grapsidae, 180 (26); and fiddler crabs, Ocypodidae, 272 (19).

Number of identifications 6,086; percentage of identifications among those of all arthopods 2.8877; percentage of species in this group among the whole number of arthropod species known, 3.8254.

Other enemies.—Crabs of various genera (including hermits) are a staple item of food for many fishes, such as the dogfish, rays, eels, sea bass, squeteague, scup, tautog, swellfish, toadfish, tilefish, hake, cod, haddock, sculpins, and flounders. Crawfishes are relished by fresh-water fishes and are eaten also by snakes, turtles, and various mammals such as the muskrat, raccoon, skunks, mink, and otter. Such large and powerful forms as lobsters are eaten by sea bass, rockfish, tautog, sharks, dogfish, rays, and skates. Amphipods are captured by the plant *Utricularia,* by insects, hydras, sea-anemones, and starfishes. Practically all adult fresh-water fishes eat amphipods and isopods, and when young prey upon Cladocera, Copepoda and Ostracoda. Starfishes and bony fishes such as Coregonus, Salvelinus, Alosa, herring, sticklebacks, and roaches continue feeding on these small forms when adult. Marine fishes take similar crustacea available to them, particularly the abundant shrimps and Mysidacea. Whales and seals consume enormous quantities of isopods and Euphasiacea. Caprellids

are eaten by fishes as well as by birds. Cladocera and Copepoda are eaten freely by larval salamanders and to a lesser extent by recently transformed frogs. They and all other small fresh-water crustaceans fall a prey to Hydra and aquatic insects. Small marine forms are engulfed even by protozoans. Barnacles are eaten by the tautog, and by sea-anemones and sea-urchins. More than 80 kinds of crustacea have been identified from stomachs of haddock taken in waters about Scotland (Thomas Scott). Crustacea have parasites from among their own ranks, and from among the worms.

Discussion.—Most of the small crustacea are translucent or transparent but this does not save them from their foes. Practically all aquatic animals "get their start" by feeding on these crustacea, the list including a great variety of insects, fishes, and batrachians. Many of them continue feeding upon crustacea when adult, and so common is this habit that in many cases small crustacea are the animal basis of the food for the entire fauna of certain waters. This is true of the Artemia of Great Salt Lake, previously discussed, and conspicuously so of the Mysidacea, Amphipoda, Isopoda, Euphasiacea and Macrura of northern oceans, where everything from other crustacea, through fishes and birds up to whales preys incessantly upon them. There is no question of special protection here but solely of numbers and fecundity.

The protection that crustacea might be supposed to derive from their more or less indurated exoskeleton is discounted by the fact that in most cases there are plenty of enemies large enough to swallow them whole. Of what avail for instance is the bivalved shell of the almost microscopic Ostracoda? The same principle applies all along the line up to and including the crabs, for most crab-eaters swallow their prey entire; however there are some crabs that grow so large they are possibly almost free from enemies when adult.

The claws of the large decapods naturally are of little avail against enemies so voracious as to swallow the crustaceans whole and there is no evidence known to the writer that the self-mutilation practiced by decapods results in enemies swallowing the claw and letting its owner escape.

Birds find the Hippidae or sandbugs, despite their burrowing habits, and hermit crabs, adopted shell and all, are freely eaten by birds and fishes. In numerous cases the hermit crabs found in bird stomachs were those with hydroids and bryozoa growing on their carapaces or shelters. Why should it even be supposed that such combinations of animals are protective when the enemies of one of them are in most cases enemies of all? For instance the diving ducks and fishes

which relish crabs, including hermits, also eat mollusks, bryozoa, and hydroids. What difference is it to them that a mollusk shell contains a hermit crab rather than its original occupant, or that hydroids are growing on it when these animals are browsed from rocks, etc., elsewhere? McIntosh has brought up this same point with regard to species of *Hyas* which become covered with a growth of algae and invertebrates, yet covered with parasites as they are, abound in stomachs of the cod.[1] They are eaten by other fishes and by birds also. Conclusions of a similar nature undoubtedly must be drawn in the case of those crabs associating sea-anemones and ascidians with themselves. Both of these classes of animals have their enemies which probably would engulf crab and all in cases where the animals were together.

The caprellids noted by Mortensen as resembling algae and by Parker and Haswell as so closely assimilated in form and color to Hydrozoa and Polyzoa as to be difficult of detection nevertheless are detected and eaten by some birds and by numerous fishes, and the protectively formed and colored isopods of the genus *Idothea* are represented by 51 records for 6 species in stomachs of 18 kinds of birds.

The fiddler crabs (*Uca*), so abundant and conspicuous on the mud flats of the southeastern coast of the United States, have one claw enormously developed, thus having the principal characteristics of the so-called protected species, a special mode of defense, and living exposed and conspicuously in large numbers. They are freely eaten by birds however and for this single genus of a few species, we have 271 records from 24 species of birds.

Myriapoda (Thousandlegs, Centipeds)

Protective adaptations.—The centipeds and millipeds exhibit differences that would warrant their being treated as separate classes; customarily, however, they are considered together. The following remarks on their protective adaptations are quoted from F. G. Sinclair.[2]

> The means of defence possessed by these animals . . . . differ very much in the different species of Myriapods. In the Centipedes the animals are provided with a powerful weapon in the great poison claws which lie just beneath the mouth, and which are provided with large poison glands, which supply a fluid which runs through a canal in the hard substance of the claw and passes into the wound made by the latter. The effect of this fluid is

[1] Ann. Mag. Nat. Hist. 7th ser., vol. 7, p. 229, Mar., 1901.

[2] Cambridge Nat. Hist., vol. 5, pp. 36-37, 1910.

instantaneous on the small animals which form the food of the Centipedes. I have myself watched *Lithobius* in this country creep up to a blue-bottle fly and seize it between the poison claws. One powerful nip and the blue-bottle was dead, as if struck by lightning. I have also seen them kill worms and also other *Lithobius* in the same way. When another *Lithobius* is wounded by the poison claws it seems to be paralyzed behind the wound. The Millepedes, on the other hand, have no such offensive and defensive weapon. They rely for protection on the fluid secreted by the *stigmata repugnatoria* (or *glandulae odoriferae*) mentioned before. This fluid has been shown to contain prussic acid, and has a very unpleasant odour. Most of the Millepedes are provided with these glands; but in the cave Myriapods mentioned before, the animals have not to contend against so many adversaries, and these glands almost disappear. Other Myriapods defend themselves by means of the long and stiff bristles with which they are provided, e. g., the little *Polyxenus*.

Bird enemies.—Centipeds have been identified 236 times from the stomachs of 65 species of nearctic birds, and millipeds 2,598 times from 98 species. The latter were identified more than 50 times in the case of each of 12 species of birds. The highest number of millipeds found in a single stomach—that of a starling—was 40. More than a tenth of the starling's annual food in the United States consists of millipeds.

Number of identifications, 2,862; percentage of identifications among those of all Arthropoda, 1.3580; percentage of species in this class among the whole number of arthropod species known, .4781.

Other enemies.—A. H. Kirkland in his report on the "Usefulness of the American toad"[1] states that 10 per cent of the food of 149 individuals examined consisted of millipeds and that as many as 77 were found in a single stomach. Myriapods are eaten also by frogs, salamanders, lizards, snakes and turtles. Among mammals the common mole (*Scalopus*), armadillo (*Tatu*) and civetcat (*Bassariscus*) (and the mongoose as introduced into Trinidad) are known to feed on centipeds, and Brewer's mole (*Parascalops*) and the armadillo on millipeds; shrews prey upon both groups. Centipeds are eaten by predacious beetles, frequently prey upon each other, and it appears that often the male is consumed by the female following pairing. Millipeds are the chief food also of certain Lampyrid larvae, are eaten by ground beetles, and are parasitized by phorid flies.

Discussion.—There is a more or less prevalent belief that myriapods are "specially protected" animals. This idea is reflected in an article on "The hothouse milliped as a new genus," in which the author,

[1] Farmers' Bull. 196, U. S. Dep. Agr., 16 pp., 1904.

O. F. Cook, says:[1] "Prussic acid and other corrosive secretions . . . . render . . . . the millipeds distasteful to birds and other animals that might prey upon them." This statement implies that millipeds have no natural enemies, an Utopian condition that probably no animal enjoys. In fact the evidence here adduced shows that millipeds and centipeds as well, have numerous effective bird enemies, which together with special enemies in other groups, no doubt prey upon them about in proportion to their availability. From the comparatively small numbers of myriapods and their secretive habits, it could not be expected that they form a very high percentage of the food of carnivorous animals. This reasonable expectation certainly is fully satisfied by the showing here made of the activities of their natural enemies.

Insecta (Insects)

From tabulations appearing earlier in this article, it will have been noted that arthropods contribute more than 88 per cent of all the records of the animal food of nearctic birds and insects more than 90 per cent of the arthropods. To repeat the figures for the latter group, insects furnish 190,919 identifications, which is 90.5891 per cent of those of all arthropods. The percentage of species of the class Insecta among the whole number of arthropod species known is 91.8589.

Not only are insects the most numerous class of jointed animals, and the most important item of the animal food of birds, but they are also the group about which most has been written in a theoretical way as to protective adaptations (especially color) and as to the relation of these adaptations to predatory foes. On all these accounts it is desirable to discuss the insects in greater detail, certainly in most cases by orders and in some instances by families. Tabulations have been prepared, therefore, showing numbers of identifications by orders and families, with their relative percentages. The first of these is a distribution of the total number of identifications by orders.

The reader may have wondered why some of the tabulations as to relative numbers of insects have not been based on the inventories of some of the larger museums. However, this matter has been considered and the invalidating factor in such statistics is that such collections are always more or less specialized either as a result of policies of the museum or of the receipt of collections from specialists. Thus among insects, such favorite groups of the amateur as

[1] Proc. U. S. Nat. Mus., vol. 40, p. 625, 1911.

Lepidoptera and Coleoptera are always copiously represented, while such orders as Thysanura and Thysanoptera in most cases are obviously neglected. However, one museum tabulation with percentage designations added, is herewith appended as a further demonstration (notwithstanding the defects just pointed out and the approximate nature of some of its figures) that multiplicity of species is more or less closely correlated with abundance of individuals. This table is adapted from one presented by Dr. J. M. Aldrich in the Smithsonian Report for 1919 (1921), p. 373.

Summary of U. S. National Museum Collection, June 1919

Order	Named species	Total specimens	Percentage of species in this group	Percentage of specimens in this group
Thysanura	[1] 100	[1] 700	.1010	.0329
Odonata	705	16,642	.7120	.7821
Isoptera	173	[1] 100,000	.1747	4.7000
Ephemerida Plecoptera Corrodentia Mecoptera Trichoptera Neuroptera	647	14,721	.6534	.6918
Mallophaga	[1] 125	[1] 1,250	.1262	.0587
Dermaptera	180	1,098	.1818	.0516
Orthoptera	2,556	25,988	2.5815	1.2214
Hemiptera	[1] 3,876	244,637	3.9147	11.4979
Lepidoptera	30,653	275,920	30.9595	12.9682
Diptera	10,253	210,880	10.3555	9.9113
Siphonaptera	[1] 130	[1] 432	.1313	.0203
Coleoptera	[1] 32,500	[1] 738,000	32.8250	34.6860
Hymenoptera	17,638	493,757	17.8143	23.2065
Thysanoptera	200	750	.2020	.0352
Strepsiptera	159	414	.1605	.0194
Total	98,925	2,125,189		

[1] Estimated.

Identifications of Insects

Order [1]	Number of identifications	Percentage of identifications among those of all insects	Percentage of species in this group among the whole number of insect species known
Aptera	5	.0026	.1691
Odonata (further unidentified)	2,082	1.0905	...
Zygoptera	245	.1283	.2603
Anisoptera	707	.3703	.3383
All Odonata	*3,034*	*1.5891*	*.5986*
Agnatha	484	.2535	.1041
Plecoptera	80	.0419	.0780
Isoptera	129	.0677	.0911
Dermaptera	18	.0094	.1301
Cheleutoptera	26	.0136	.6507
Diphtheroptera	5,695	2.9829	.7809
Orthoptera (Sens. str.)	6,280	3.2893	.8589
Paleoptera	117	.0613	.3123
Dictyoptera	58	.0304	.2082
Saltatoria (further unidentified)	6,450	3.3784	...
Orthopteroidea (further unidentified)	359	.1880	...
All Orthopteroidea	*19,003*	*9.9534*	*2.9410*
Corrodentia	17	.0089	.0780
Mallophaga	6	.0031	.3383
Siphonaptera	1	.0005	.0130
Heteroptera	11,530	6.0392	4.9457
Homoptera	5,215	2.7315	3.6442
Hemiptera (further unidentified)	5,650	2.9594	...
All Rhynchota	*22,395*	*11.7300*	*8.5899*
Neuroptera (Sens. lat.)	119	.0623	...
Megaloptera	167	.0875	.0156
Rhaphidioidea	54	.0283	.0104
Neuroptera (Sens. str.)	108	.0566	.3383
Phryganoidea	866	.4536	.3644
All Neuropteroidea	*1,314*	*.6882*	*.7187*
Lepidoptera	18,487	9.6831	15.6180
Coleoptera	85,322	44.6899	46.2032
Mecaptera	5	.0026	.0260
Diptera	10,836	5.6757	11.4432
Hymenoptera	27,025	14.1551	17.1798
Unidentified	2,676	1.4016	...

[1] The arrangement of the orders of insects in this tabulation is a compromise among several systems.

There are no accounts given of Platyptera (embiids), Zoraptera, Notoptera (grylloblattids), Siphunculata (body lice), Apocoleoptera (beaver beetles), and Suctoria (fleas) because we have no records of bird enemies.

Total number of identifications, 190,919; percentage of identifications among those of all arthropods, 90.5891; percentage of species in this class among the whole number of arthropod species known, 91.8589.

APTERA (WINGLESS INSECTS)

Protective adaptations.—The springtails and their allies appear to have few adaptations such as are commonly called protective, their defense being agility in some cases, and secretive habits in others. Some species have coxal glands supposed to be repugnatorial.

Bird enemies.—While only five records of Thysanura are included in the tabulations here reported upon others have been made since and it seems probable that birds which feed about small pools, on the quiet surface of which Collembola sometimes abound, or on the edges of snowfields, will be found to pay due attention to thysanurans.

Total number of identifications, 5; percentage of identifications among those of all insects, .0026; percentage of species in this group among the whole number of insect species known, .1691.

Other enemies.—In reports of the Pennsylvania Department of Agriculture and others treating the same groups of animals, seven species of salamanders, four of frogs, and one toad are recorded as feeding on Thysanura. Hamilton, reporting on 400 stomach contents of young toads, says: "Collembola comprised 6.2 per cent of the diet. The springtails sometimes occurred in large numbers in the stomachs examined, and together with thrips appeared to be an important food of all small anurans" (Copeia, 1930, p. 45). Forbes reports them being eaten by a Coccinellid beetle[1] and a small fish[2] (*Labidesthes sicculus*), Needham, by the brook trout,[3] and Pearce by two species of fishes, a killifish and the mudminnow.[4] They are known to be preyed upon also by aquatic hemiptera, and are cannibalistic.

Discussion.—Thysanura are chiefly minute insects, many of which spend their whole lives in well-concealed places. The forms which live more or less exposed appear to have enemies among animals interested in such small morsels of food. However information on the subject thus far is inadequate and no doubt will be increased by more intensive investigation of potential predators.

[1] Bull. Ill. State Lab. Nat. Hist., vol. 1, no. 6, p. 52, May, 1883.
[2] Op. cit, vol. 2, p. 525, 1888.
[3] Bull. 68, N. Y. State Mus., p. 205, 1903.
[4] Bull. U. S. Bur. Fisheries, vol. 35, p. 285 (1915-16), 1918.

ODONATA (DRAGONFLIES, DAMSELFLIES)

Protective adaptations.—Dragonflies are fairly large, powerful, predacious insects with remarkable ability for flight. They are held in fear by illiterate people, a feeling possibly inspired by the large mobile head consisting chiefly of eyes, and the strikingly contrasted color-pattern of many of them. A dark ground color with vivid spots of green or yellow, answering to the description of warning color, is common among dragonflies; some also have brilliant red, blue, and metallic colors.

On the other hand, members of the order known as damselflies in general are weak on the wing and of slighter and more delicate structure. Some of them also are brightly colored but many are dull. The immature stages of both dragonflies and damselflies are aquatic, and predacious, and invariably inconspicuously colored.

Bird enemies.—It might perhaps be expected that damselflies would be more frequently captured by birds than dragonflies, but this does not seem to be the case, the determinations for these groups so far standing at 245 damselflies and 707 dragonflies. However, 2,082 identifications do not indicate which suborder is concerned. About 200 species of birds are known to eat Odonata, and nymphs as well as adults are freely taken. No fewer than 100-125 nymphs have been taken from the gullet and gizzard of individual ducks, yellow-legs, and magpies. Regarding the adults, Needham says: "It is doubtful whether anything that flies is able to capture in flight one of the swiftest dragon flies."[1] However, we have records of birds eating *Epiaeschna heros,* one of the largest and swiftest of the dragonflies of the United States, and *Anax junius,* another of the giant species, is commonly eaten by the pigeon hawk. No fewer than 28 individuals of Anax were found in a single stomach of this falcon, and adult dragonflies, mostly *Anax junius,* were found in 120 out of 181 stomachs of the species. In a lot of dragonfly wings, picked up under the home of a colony of purple martins at West Chester, Pa., were represented about 63 individual dragonflies, largely *Epiaeschna heros,* but including also, *Anax junius, Libellula pulchella,* and *Anax longipes.*

Number of identifications, 3,034; percentage of identifications among those of all insects, 1.5891; percentage of species in this group among the whole number of insect species known, .5986.

Other enemies.—Odonata are notoriously cannibalistic both in the nymphal and adult stages. Diving beetles, water scorpions and other

[1] In Ward and Whipple, Fresh-water biology, p. 890, 1918.

aquatic hemiptera, salamanders, frogs, turtles, and many kinds of fishes prey upon the nymphs. Ants, spiders, robber flies, chipmunks, snakes, frogs, toads, and fishes feed to some extent also on adult dragonflies, obtaining most of them no doubt when teneral. They are parasitized by nematodes, mites, and flies.[1]

Discussion.—Odonata, both immature and adult, are freely preyed upon by a variety of enemies and no special defense can be assumed except the great expertness in flight of some of the dragonflies. This we have seen does not foil various birds nor of course predators from their own ranks. All in all it would seem that Odonata are preyed upon fully in proportion to their abundance.

AGNATHA (MAYFLIES)

Protective adaptations.—The nymphs that live in water are plainly colored; some cling closely to various objects in their environment, while others swim in a rapid darting manner. The adults also are usually inconspicuously colored.

Bird enemies.—Our tabulation shows mayflies to have been identified from the stomachs of 108 species of nearctic birds. A nighthawk has been known to contain 400 adults at one time or many thousands of eggs, the remains of the digestion of adults. As many as 250 nymphs have been found in a godwit's stomach. Mayflies periodically are exceedingly abundant and then are preyed upon by practically all kinds of insectivorous birds. An interesting account of the behavior of birds in the presence of a swarm of ephemerids is given by Dr. S. D. Judd in his "Birds of a Maryland Farm";[2] on this occasion 40 species of birds were observed eating mayflies. This list adds nine to the species of birds known from stomach examination to feed upon mayflies.

Number of identifications, 484; percentage of identifications among those of all insects, .2535; percentage of species in this group among the whole number of insect species known, .1041.

Other enemies.—Mayfly nymphs are eaten by the nymphs of stoneflies and dragonflies, by water bugs, most fresh-water fishes, and to some extent by salamanders and turtles; the adults are preyed upon by fishes and adult dragonflies, spiders, toads, and bats.

Discussion.—Mayflies are good food for predacious animals and are eaten freely, so much so as to cause David Sharp to remark:[3] "That

[1] For full discussion of dragonfly enemies, see Bull. U. S. Bur. Fisheries, vol. 36, pp. 209-211 and 222-232 (1917-18), 1920.

[2] Bull. 17, U. S. Biol. Survey, pp. 22-24, 1902.

[3] Cambridge Nat. Hist., vol. 5, p. 442, 1910.

insects so fragile, so highly organized, with a host of powerful enemies, but themselves destitute of means of attack or defense, should contrive to exist at all, is remarkable." Doctor Sharp here falls into the same error the selectionists often do, namely, of taking the struggle for existence too seriously. While mayflies are a favorite food of many predators, the evidence does not indicate that they are eaten out of proportion to their numbers. They are also very fecund, practically the whole body content of a female mayfly consisting of the two egg masses. The annual occurrence of swarms covering the foliage along streams (dating back as far as such things were recorded) is proof enough that enemies do not permanently reduce the numbers of mayflies, and furthermore that the so-called defenses or protective adaptations, of which mayflies are so nearly destitute, are not essential to the maintenance of species in large, even overwhelming numbers.

PLECOPTERA (STONEFLIES)

Protective adaptations.—The stoneflies are mostly plainly colored but some are rather bright yellow; they are poor fliers but some of them are said to emit a liquid from the basal articulations of the legs, a performance usually classed as protective. The nymphs are aquatic in habit, good swimmers, and obscure in color.

Bird enemies.—Stoneflies have been identified in the stomachs of 41 species of nearctic birds, usually in no very large numbers. The total number of identifications is 80; the percentage of identifications among those of all insects, .0419; and the percentage of species in this order among those of all insect species known, .0780.

Other enemies.—Dragonfly nymphs prey upon those of stoneflies, and a few fishes, salamanders, frogs, and turtles feed upon these insects, either in the immature or mature condition according to availability. Needham says: "Hudson has demonstrated the importance of stoneflies as fish food in the mountain streams of New Zealand" (Fresh-water Biology, 1918, p. 884), and Muttkowski reports that 90 per cent of the food of trout in Yellowstone National Park consists of them.

Discussion.—The Plecoptera are a small group of insects of restricted habitat, one we should therefore not expect to find preyed upon extensively. They are eaten by various enemies, however, more or less in proportion to their abundance, and the evidence does not seem to indicate that special defenses of any kind enter into the equation.

ISOPTERA (TERMITES)

Protective adaptations.—Termites pass most of their lives concealed in galleries in wood or underground or in well-built nests. They have strong jaws, a caste of soldiers especially well-armed in this respect, and they emit a corrosive secretion. The color is usually yellowish to brownish, but some species have the body reddish and the wings dark, nearly black, thus having a coloration approaching that termed warning.

Bird enemies.—Stomach examination has revealed termites in the dietary of 38 species of nearctic birds. The occasions when termites are available to most birds are infrequent, but when they come, the insects usually are in great abundance. Accordingly large numbers are eaten, and single stomachs have yielded as many as 215 termites in the case of a nighthawk, 400 in that of a pileated woodpecker, and 1,100 in that of a flicker. The writer has twice observed numbers of English sparrows gobbling up termites upon emergence and Hagen has recorded [1] a case in which 15 species of birds were in attendance on a swarm of white ants, the robins among them so gorging themselves that their bills stood open.

Number of identifications, 129; percentage of identifications among those of all insects, .0677; percentage of species in this group among the whole number of insect species known, .0911.

Other enemies.—Termites are as much sought after by some other animals as they are by birds and even are eaten by man. It has been said that in the Tropics "The flight of the winged termites is a great event in the animal year." [2] In India cockroaches, frogs, lizards, rats, bats, jackals, mongooses, jungle cats, and dogs have been observed [3] preying upon them. In the United States, besides wild birds and domestic fowls, salamanders, frogs, toads, lizards, spiders, centipeds, crickets, robberflies, ants, and beetle larvae prey upon termites. The insects have parasites also among the fungi, protozoa, nematodes, and mites.[4]

Discussion.—The enemies of termites are comparatively well-known, not wholly because they are numerous or active, but also because termites are "economic" insects and have therefore been the subject of considerable study from many points of view. Although

[1] Hagen, H., Proc. Boston Soc. Nat. Hist., vol. 20, p. 118, (1878-1880) 1881.

[2] Longstaff, G. B., in Shelford, R., Naturalist in Borneo, p. 37, 1916.

[3] Rothney, G. A. J., Proc. Ent. Soc. London, 1918, pp. lxiv-lxvi.

[4] For an account of these miscellaneous enemies, see Snyder, T. E., U. S. Nat. Mus. Bull. 108, pp. 116-118, 1920.

they have protective adaptations of various kinds, termites are eaten freely by numerous animals. Birds prey upon them eagerly when occasion offers, but on the whole not out of proportion to the abundance of the insects.

ORTHOPTEROIDEA

Group	Number of identifications	Percentage of identifications among those of all Orthopteriodea	Percentage of species in this group among the whole number of nearctic Orthopteroidea [1]
Unidentified	6,809	35.8310	...
Dermaptera	18	.0947	1.8494
Paleoptera	117	.6157	4.4194
Dictyoptera	58	.3052	2.1136
Cheleutoptera	26	.1368	1.4531
Diphtheroptera	5,695	29.9688	69.3525
Orthoptera	6,280	33.0472	20.7397

DERMAPTERA (EARWIGS)

All earwigs have pincer-like appendages at the end of the abdomen, the function of which is little understood. One suggestion is that they are for defense, but in what way they might serve for this purpose is not clear. Many earwigs have glands producing a fetid secretion. These insects in general are inconspicuous but a few have brilliant colors. Earwigs are seldom met with in the United States and the record of their bird enemies is short—18 identifications in the stomachs of 15 species of birds. Percentage of identifications among those of all insects, .0094; percentage of species in this group among the whole number of insect species known, .1301. That this result is merely a reflection of the infrequency of earwigs is indicated by the fact that in Great Britain where these insects are much more common, the records of birds eating them are proportionately higher. Thus Robert Newstead,[2] treating of a mere fraction of our number of stomach examinations gives records for seven species of birds and notes that 23 earwigs were found in the stomach of a green woodpecker and 40 in that of a whimbrel. F. V. Theobald and William McGowan in their report[3] on "The Food of the Rook, Starling and Chaffinch," note that each of these birds prey upon earwigs, and

[1] Computed from Scudder, S. H., Catalogue of the described Orthoptera of the United States and Canada, Proc. Davenport (Iowa) Acad. Nat. Sci., vol. 8, 101 pp., 3 pls., 1900.

[2] Suppl. Journ. Board Agr. [London], vol. 15, no. 9, Dec., 1908.

[3] Suppl. Journ. Board Agr. [London], vol. 15, no. 15, May, 1916.

W. E. Collinge records[1] five species of birds as feeding on these insects. Among other enemies of earwigs are batrachians, of which 6 species of salamanders, and 16 of frogs have been recorded in the United States as feeding on Dermaptera. The earwigs are neither an extensive nor an abundant group of insects and we should not expect to find them preyed upon by insectivorous animals to any marked degree.

CHELEUTOPTERA (WALKINGSTICKS)

Protective adaptations.—As their vernacular names, stick and leaf insects imply, these insects bear resemblances to objects in the vegetable kingdom that have caused them to be considered as having reached the very acme of protective adaptation. "Some," says David Sharp,[2] "look like sticks, or stems of grass; some have a moss-like appearance, while others resemble pieces of lichen-covered bark. The members of the tribe Phyllides are leaf-like. A certain number ... are covered with strong spines, like thorns. Some, if not all, of the Phasmidae," he adds, "have the habit of ejecting a stinking fluid that is said to be very acrid" (264). The eggs of walkingsticks are peculiar in shape and sculpturing and many of them resemble seeds.

Bird enemies.—Records of walkingsticks in the identifications of bird food here discussed total 26, and pertain to 18 species of birds. The crow blackbird heads the list with seven captures.

Percentage of identifications among those of all insects, .0136; percentage of species in this group among the whole number of insect species known, .6507.

Other enemies.—Predacious hemiptera, mantids, lizards, and spermophiles may be mentioned among the enemies of stick-insects, and ichneumon flies are said to parasitize both adults and eggs.

Discussion.—The apparent discrepancy in the indices of frequency of occurrence of stick-insects in bird food and in nature is to be explained by the relatively poor representation of this group in the United States, we having but 11 species. If we grant that the form, color, and sluggishness of these insects has a protective value in relation to predators, we must admit that these qualities facilitate also the destruction of the walkingsticks by grazing animals, which engulf indiscriminately huge mouthfuls of browse together with any insects thereon that are not agile enough to beat an instantaneous retreat. In the same way if the resemblance of the eggs to seeds is to be

[1] The food of some British wild birds, 1913.

[2] Cambridge Nat. Hist., vol. 5, p. 260, 1910.

regarded as significant, it would appear to put these objects in jeopardy, as the proportion of the food of birds and other animals made up of seeds is immensely greater than that composed of insect eggs. Judged as a protective adaptation, therefore, this case would seem to fit the old adage of "out of the frying-pan into the fire." Two authorities who have paid special attention to the subject, however, conclude that the resemblance to seeds of these eggs has no bionomic importance.[1]

SALTATORIA (GRASSHOPPERS, LOCUSTS, CRICKETS)

Owing to the facts that identifications in hundreds of cases were not carried as far as they might have been, and that it is impracticable to tabulate them by families, we put all the leaping orthoptera together, rather than consider separately the two orders into which these forms are usually grouped.

For convenience part of the tabulation of identifications is here repeated in revised form.

Identifications of Saltatoria

Group	Number of identifications	Percentage of identifications among those of all Saltatoria
Diphtheroptera (Grasshoppers, locusts)	5,695	30.3185
Orthoptera (Sens. str.) (Green grasshoppers, katydids, crickets)	6,280	33.4328
Saltatoria (Further unidentified)	6,450	34.3378
Orthopteroidea (Further unidentified, no doubt Saltatoria)	359	1.9112
All Saltatoria	18,784	

Protective adaptations.—A. R. Wallace says:[2] "The whole order of Orthoptera, grasshoppers, locusts, crickets, etc., are protected by their colours harmonising with that of the vegetation or the soil on which they live, and in no other group have we such striking examples of special resemblance."

With special reference to American insects, A. P. Morse makes the following statement:[3] The coloration

is, with few exceptions, highly sympathetic in character, harmonizing with or resembling very closely, often to a marvelous degree, the background of the

[1] Sharp, D., Willey Zool. Results, Cambridge, 1898, p. 75-94.
Severin, H. H. P., Ann. Ent. Soc. Amer., vol. 3, pp. 83-92, 1910.
[2] Natural selection and Tropical nature, p. 46, 1891.
[3] Proc. Boston Soc. Nat. Hist., vol. 35, no. 6, p. 244, 1920.

insect's environment. Earth tints, rock and sand textures, the infinitely varied browns, greens, and grays of living and dead vegetation, yellow, orange, rose, and silvery white are all represented in spots and streaks, the effect being to merge the insect indistinguishably into its background while at rest, thus shielding it in a very high degree from the observation of its foes. These colors are of great protective value at the present time, natural selection continually acting to preserve and perfect them, but though highly protective in character, they are without doubt primarily due to physiological processes and influences as yet imperfectly understood.

This type of coloration is admirably illustrated among New England species by the Seaside Locust and Sand Locust which live on sandy backgrounds, the Snapping and the Ledge-loving Locusts on rock habitats, the Coral-winged and the Clear-winged Locusts in fields; and in the plant-perching species the Pine-tree Locust with its background of lichened pine bark, the Red-legged and the Two-striped Locusts among the yellowish green of herbage, and other species of *Melanoplus,—M. mancus, M. fasciatus,* etc.,—whose darker tints resemble those of fallen leaves from the *Vaccinium* thickets amid which they live.

One who has not watched these creatures out of doors can appreciate to but a slight degree the effectiveness of sympathetic coloring as a means of concealment. Let him but try to pick out from its background immobile grass-green Cone-head, leaf-brown Shield-backed Grasshopper, or any of the Locusts just mentioned, and he will realize as never before the importance to the defenceless insect of Mother Nature's protective mantle of invisibility.

The wing-covers of certain katydids and allied forms are very leaflike, the resemblance being carried so far in certain cases, it is said, that the spots like those due to fungi and the tracks of leaf-mining insects are closely imitated.

The leaping powers of the Saltatoria, remarkably developed in some forms, must be classed as defensive; most of these insects have powerful mandibles also, a few of them indeed being markedly carnivorous.

Locusts of the subfamily Oedipodinae, especially, have another adaptation some consider protective. For instance E. B. Poulton says:[1] "The brightly coloured hind wings of many moths (*Catocala, Tryphaena,* etc.) and grasshoppers (*Oedipoda,* etc.) which flash out conspicuously when the insect becomes active, and disappear equally suddenly when it alights, probably serve, as Lord Walshingham has suggested [Proc. Ent. Soc. Lond. 1890, pp. l-liii], to confuse a pursuing enemy." It may be noted that Morse considers these colors as recognition markings.

Finally, among protective adaptations, certain Orthoptera are said to mimic other insects, as for instance Membracidae, Phasmidae, ants,

[1] Essays on evolution, p. 303, 1908.

and beetles, though we have none of these forms in the United States; the mole crickets and a few other forms have special fetid secretions, and the brown drop that so many orthoptera exude from the mouth when captured is said to be a protective device.

Bird enemies.—Nearly a tenth of all the identifications of insects in bird stomachs are of leaping orthoptera. To name the birds that eat grasshoppers is to name all birds not strict vegetarians. When these insects are abundant, birds of all sizes turn their attention to the Orthoptera and for the time being make them a staple food. As a constant article of diet also, they are important to many birds. The number of identifications of Saltatoria from stomach contents was 50 or more in the case of over 20 species of birds, more than 100 in 22 additional species, more than 200 in 10 other species, in excess of 1,000 in two cases, namely, of the common crow, and the meadowlark, and more than 1,500 for the starling and crow blackbird. Expressed in proportions of the annual subsistence of certain birds most fond of the insects, we find according to Biological Survey records that Saltatoria compose 21.29 per cent of the food of the western bluebird (based on the examination of 217 stomachs), 22.01 per cent for the eastern bluebird (855); grasshopper sparrow (170), 23 per cent; the eastern and western meadowlarks combined (1,514), 26.08 per cent; the Arkansas kingbird (109), 27.76 per cent; Franklin's gull (93), 43.43 per cent; and the scissor-tailed flycatcher (129), 46.07 per cent.

These are illustrations of the relations of birds to leaping orthoptera under normal conditions. When species of these insects become excessively abundant as they frequently do, the gathering of the bird clans to feed upon them is proverbial. No instance is more celebrated than that studied by Prof. Samuel Aughey during an invasion of the Rocky Mountain locust in Nebraska. He found locusts in the stomachs of no fewer than 172 species of birds varying in size from the tiny hummingbirds up to the largest hawks, and including such usually exclusively vegetarian birds as the passenger pigeon and mourning dove. Professor Aughey was eye-witness also to 33 additional species of birds preying upon the locusts.[1]

For a modern illustration of the same phenomenon, we may cite a brief investigation made by the Biological Survey during a grasshopper outbreak in South Dakota in 1920. Out of the 26 species of birds collected, representatives of 24 had been eating the hoppers; of 19 species every bird collected had taken grasshoppers, and for the

[1] Notes on the nature of the food of the birds of Nebraska. First Ann. Rep. U. S. Ent. Comm. (1877), App. II, pp. [13]-[62], 1878.

species eating them, the insects composed from 40 per cent to 90 per cent of the total food.

In another study of the effect of birds upon a severe irruption of grasshoppers in California, H. C. Bryant estimated that birds were destroying *daily* more than 120,000 grasshoppers per square mile in the infested area.[1]

In countries, notably Africa, where migrations of large numbers of locusts are of regular occurrence, various species of birds have more or less specialized in following these flights and feeding on the migrants, so much so, in fact, as to earn for themselves the name of locust birds.[2]

Number of identifications of Saltatoria, 18,784; percentage of identifications among those of all insects, 9.6506; percentage of species in this group among all insect species known, 1.6398.

Other enemies.—All stages of the Saltatoria are much sought for by various animals. The larvae of Cantharid beetles and of bee flies (Bombyliidae) subsist upon the eggs, as do also certain mites, and the egg masses of some species are dug up and devoured by various mammals, as moles, mice, spermophiles, and skunks. The nymphs and adults fall a prey to vertebrates of nearly all sizes and descriptions, ranging from bears, through coyotes, foxes, badgers, skunks, civetcats, weasels, wood rats, squirrels, spermophiles, moles, shrews, and mice, to lizards, tortoises, snakes, salamanders, frogs, and toads. If any seek to escape their land enemies by jumping into the water, they are snapped up by fishes. The adults are destroyed in large numbers by parasitic diptera and hymenoptera. Most of the predatory invertebrates are fond of grasshoppers, this being particularly true of dragonflies, tiger beetles, ground beetles, robber flies, digger wasps, and spiders. In the case of the latter, S. W. Bilsing found grasshoppers in 20 per cent of the webs of *Epeira trifolium*, in 35 per cent of those of *Argiope riparia*, 44 per cent of those of *A. trifasciata*, and in 53 per cent of those of *Agalena naevia*. Grasshoppers are parasitized by nematodes and protozoa and are subject to bacterial and fungal diseases, which last are said sometimes to destroy them "in myriads."

Discussion.—The Saltatoria or leaping Orthopteroidea are prominent in the insect world more through average large size and the

[1] Univ. California Publ. Zool., vol. 11, no. 1, pp. 16-17, Nov. 1, 1912.

[2] See Badenoch, L. N., True tales of the insects, pp. 127-128, 1899; La Baume, W., Beihefte z. Tropenpflanzer, vol. 11, no. 2, pp. 65-128, Apr., 1910; Agr. Journ. Cape of Good Hope, vol. 18, pp. 820-833, 1901; vol. 19, pp. 99-106, 165-171, 248-262, 1901; vol. 28, pp. 364-366, 1906; Trans. South African Phil. Soc., vol. 1, p. 193, 1880.

abundance of individuals rather than through abundance of species. Almost everywhere in the United States that herbage is plentiful, grasshoppers in the late summer rattle away from the approaching pedestrian in such numbers as to form a veritable rolling barrage of insect projectiles. No insects are more conspicuous in action, yet on close examination the observer finds that the individual hopper is dull and obscure in color. The point is worthy of attention because it proves that the formula that abundant and conspicuous insects tend to be warningly colored and inedible has numerous exceptions. None of our grasshoppers of the northeastern United States are warningly colored, unless the Oedipodinae with brightly and contrastingly colored hind-wings, and in many instances a loudly rattling flight, may be so considered. Whatever their status in adaptation theories such genera as *Arphia, Dissosteira,* and *Hippiscus* seem to supply their full quota to the food of birds and other predatory enemies. On the other hand some of the "sympathetically" colored species mentioned in the remarks on adaptations quoted from Morse are the very bread of avian diet. Grasshoppers of the genus *Melanoplus* for instance were identified 543 times among the records here considered, and were found in the stomachs of more than 85 species of birds. These and other Acridids are taken not only frequently but often in quantity, for instance, the remains of no fewer than 123 specimens were found at one time in the stomach of a common crow and 340 in that of a Franklin's gull. Judging from the records, the green grasshoppers or Locustidae and the crickets also bear their appropriate burden of predatory attack.

The imposing total of 17,641 identifications of Saltatoria, more than a tenth of all insect determinations, shows what an important staple for the birds these creatures are, and how poorly their prevailing elaborately cryptic coloration succeeds in foiling their enemies. They are preyed upon voraciously not only by birds but by a host of other animals, but the effect of the attacks of predators, parasites, and diseases together in no way suggests that the Saltatoria are a disappearing race. Despite persecution, these insects abound and the reasons are high fecundity and the great surplus of food available to them; these are substantial realities and outweigh immeasurably those airy intangibilities classed as protective adaptations.

PALEOPTERA (ROACHES)

Protective adaptations.—The comparatively few native species of roaches in the United States are secretive and nocturnal in habit but appear to have no other special protective adaptations. The introduced

species live chiefly in structures of man hence have little relation to the indigenous fauna.

Bird enemies.—Thirty-six species of birds share the 117 identifications of roaches in the food of nearctic birds. The number of records was 10 or more in the case of four species of birds, and the number of specimens eaten was as high as 10 in two instances but usually was less.

Percentage of identifications among those of all insects, .0613; percentage of species in this group among the whole number of insect species known, .3123.

Other enemies.—Roaches seem to be more or less regularly eaten by toads, frogs, the armadillo, spiders, rats, scorpions, and wasps. They have specific parasites among the Evaniidae.

Discussion.—Owing to the poverty of the roach fauna of the United States, research here is not likely to throw much light on relations of these insects and their adaptations to predators. Tropical species are said to resemble various other organisms, including isopods, myriopods, longicorn, and coccinellid beetles, and hemiptera of the family Miridae. But since all of these models themselves are freely eaten by predators, the significance of the resemblances is hardly that usually attributed. In the United States natural enemies would seem to be proportional to the scanty population of native roaches.

DICTYOPTERA (MANTIDS)

Like the roaches, the mantids of the United States are few in number and do not exhibit the unusual modifications displayed by some of the tropical representatives of the group. The principal defenses of our species must be their comparatively large size among insects and their highly predatory nature. However, these characteristics are of little avail against still larger predators and we find these insects taken by birds in numbers probably bearing no distant relation to the frequency of mantids in the country. Number of identifications, 58; percentage of identifications among those of all insects, .0304; percentage of species in this group among all insect species, .2082 (for the world, of course). The number of species of birds concerned in the records here cited is 21. Mantids are eaten also by lizards.

CORRODENTIA (PSOCIDS)

The Psocidae, which include the booklice seen in houses, are delicate and minute insects. Many of the out-of-door species are winged and the wings bear color patterns which may assimilate the

insects more or less to the bark surface upon which many of them dwell. These insects mostly below the size of food objects ordinarily taken by birds were identified 17 times in the stomachs of nine species of birds. In one case, that of a chimney swift the stomach contained hundreds of specimens, gleaned no doubt from a swarm on the wing.

Percentage of identifications among those of all insects, .0089; percentage of species in this group among the whole number of insect species, .0780.

MALLOPHAGA (BITING LICE)

The only opportunity birds have to get these usually minute insects is to capture those parasitic on their own bodies, or in the case of raptorial birds to engulf some with their prey. Apparently either of these occurrences is rare; six records for as many species of birds being all included in the present tabulation. Percentage of identifications among those of all insects, .0031; percentage of species in this group among all insect species, .3383.

SIPHONAPTERA (FLEAS)

Only a single instance of a flea being eaten by a bird has thus far come to light; the opportunities for getting these small agile insects must be very few since our native birds are parasitized by fleas to only a very slight extent. That fleas are in no way distasteful (as food) to some of their hosts is evident to anyone who has observed dogs, monkeys, and other animals in their persistent and often successful search for these pests.

Percentage of identifications among those of all insects, .0005; percentage of species in this group among all insect species, .0130.

THYSANOPTERA (THRIPS)

Protective adaptations.—Some are contrastingly black and white colored and the immature stages of many are red. It is doubtful however if these colors have any warning significance. The small size and secretive habits of these insects doubtless are the most effective factors in restricting predation upon them.

Bird enemies.—No identifications of thrips appear in the analyses of the stomach contents of nearctic birds here reported upon. Wetmore reports a thrips from the stomach of a hummingbird (*Anthracothorax viridis*) from Porto Rico. (Bull. 326. U. S. Dep. Agr., p. 73, 1916.)

Other enemies.—Thrips are eaten by small predacious hemiptera, especially Anthocoridae, and egg parasites are known. Hamilton

(Copeia, 1930, p. 45) says of 400 young toads examined, "Thrips formed 10.1 per cent of the food, but were found in all but a few stomachs. These small insects appear to be a staple article of diet for young *Bufo*."

Discussion.—Thrips are too small for most birds to notice, but considering our ignorance of the subject, the notes on enemies given indicate that they have foes, the character and number of which, probably as in other cases, are regulated largely by the factor of availability.

RHYNCHOTA (BUGS, CICADAS, LEAFHOPPERS, SCALE INSECTS)

For the reason that the term Hemiptera in a broad sense was used for about one-fourth of all the identifications of Rhynchota, it is not practicable entirely to separate Heteroptera and Homoptera. However the identifications of these groups are distributed as far as possible to families in the tables presented. In using these tables, it should be kept in mind that could the incomplete determinations have been distributed, the figures would average about a fourth higher throughout.

Protective adaptations.—The popular expression 'a nasty bug' undoubtedly has reference, in most instances, to insects of this order, many of which produce scents disagreeable to human senses. Theorists have assumed these must also be repulsive to animal predators, a doctrine briefly stated in the following quotation from E. B. Poulton: "The Heteroptera (Hemiptera) are obviously, as a whole, a specially protected group, commonly defended by taste or smell from large numbers of insect-eating animals."[1]

A great series of Heteroptera are more or less aquatic in habit and thus are screened from the attacks of purely terrestrial enemies. Some are very active, as the Saldidae and many Miridae; some are said to be "mimics," as for example immature Nabidae resembling ants and certain Reduviidae resembling wasps.

Mimicry, so-called, is exemplified among the Homoptera, also, as some Fulgoridae are considered to resemble Lepidoptera in appearance. The Membracidae with a host of bizarre forms, are thought to present cases of mimicry to ants, and of resemblance to thorns and seed pods of plants. One author further remarks: "Evidently the strong pronotal processes, which are often sharp and hard enough to pierce the skin if the insect is seized suddenly, are unpalatable and irritating."[2] Quoting Poulton again (op. cit., p. 4): "Allusion must

[1] In Buckton, G. B., A monograph of the Membracidae, separate, p. 3, 1903.
[2] Funkhouser, W. D., Mem. 11, Cornell Univ. Agr. Exp. Sta., p. 417, June, 1917.

be made to the special and curious defence by a waxy secretion which is common in the Homoptera. The method may be compared to the defensive silken walls of the cocoon in other insects, while the long trailing filaments of wax borne by certain species of Homoptera may play the same part as the 'tails' on the hind wings of many Lepidoptera, or the 'tussocks' of hair on some of their larvae—all these probably acting as directive structures which divert the attention of an enemy from the vital parts."

Many plant lice have the waxy filaments alluded to by Poulton, while most of them exude special secretions from the cornicles, supposed to be protective. Leafhoppers of various groups have been thought to resemble color or structural details of plants they frequent, and as for scale insects, their small size, waxy secretions and great resemblance to the bark upon which they rest, have given them high rank among the theoretically protected insects. Indeed they have been thought well-nigh immune to attack and one author has intimated that birds never eat scale insects. (Smith, J. B., Proc. State Hort. Soc. N. J., vol. 29, p. 90, 1904.)

Bird enemies.—Below are tabulations of the identifications of Hemiptera in the stomach contents of nearctic birds followed by supplemental comment. Comparative percentages are not given for the plant lice, scale insects, and mealybugs as these have not been catalogued with the same degree of thoroughness as the other groups.

Total number of identifications of Hemiptera, 22,395; percentage of identifications among those of all insects, 11.7301; percentage of species in this order among those of all insect species known, 8.5899.

The Corixidae, although they spend practically all of their existence in water and usually on the bottom, do not thereby secure immunity from bird enemies.

Like other hemiptera, however, they are supposed to be specially protected, one author saying:

> As to the function of the stink-apparatus in the adult *Corixa,* there is no need to look beyond defence. The insect frequently leaves the water, and it is then exposed to all the dangers met with by the land Heteroptera. Also there is no reason to doubt that the odoriferous secretion is equally efficacious against enemies in water.[1]

Results indicate that this efficacy is nothing remarkable; indeed it is a fallacy to suppose that so abundant and accessible a group does not pay due toll to predators. The number of species of birds that

[1] Brindley, Maud D. Haviland, On the repugnatorial glands of Corixa, Trans. Ent. Soc. London, vol. 77, p. 13, 1929.

Identifications of Rhynchota

Group	Number of identifications	Percentage of identifications among those of all Rhynchota	Percentage of species in this group among the whole number of nearctic Rhynchota [1]
Unidentified	5,650	27.5325	...
Heteroptera (further unidentified)	389	1.8956	...
Scutelleridae	187	.9112	.8673
Cydnidae	232	1.1305	1.5677
Pentatomidae	5,582	27.2011	5.5037
Coreidae	395	1.9248	4.1361
Aradidae	15	.0731	2.0014
Neididae	17	.0828	.2668
Lygaeidae	524	2.5334	2.8353
Pyrrhocoridae	18	.0877	.7338
Tingitidae	66	.3216	2.3349
Enicocephalidae	...	...	.0667
Phymatidae	19	1.0926	.4003
Reduviidae	633	3.4846	3.7692
Hebridae	2	.0097	.1334
Mesoveliidae	16	.0780	.0334
Nabidae	163	.7943	.7005
Cimicidae	2	.0097	.1334
Anthocoridae	3	.0146	1.1007
Termatophylidae	...	...	.0334
Miridae	518	2.5242	14.8101
Isometopidae	...	...	.1334
Dipsocoridae	...	...	.1001
Schizopteridae	...	...	.0334
Hydrometridae	22	.1072	.0667
Gerridae	228	1.1110	.6671
Veliidae	32	.1559	.6004
Saldidae	74	.3606	1.0674
Notonectidae	327	1.5935	.6004
Naucoridae	306	1.4911	.4336
Nepidae	40	.1949	.2668
Belostomidae	326	1.5886	.6671
Gelastocoridae	3	.0146	.2001
Ochteridae	...	...	.1001
Corixidae	1,391	6.7783	2.0347
Homoptera (further unidentified)	107	.5214	...
Cicadidae	556	2.7094	2.7685
Cercopidae	102	.4970	.8673
Membracidae	960	4.6781	6.2042
Cicadellidae	1,435	6.9927	25.0837
Fulgoridae	59	.2875	11.9414
Psyllidae	122	.5945	4.7365

[1] Computed from Van Duzee, E. P., Catalogue of the Hemiptera of America north of Mexico, excepting the Aphididae, Coccidae and Aleurodidae. Univ. California Publ. Ent., vol. 2, 902 pp., 1917.

feed upon them shown by the present tabulation is 85 and the number of specimens taken at a meal ran over 200 in several cases, and up to 1,300 in one instance (eared grebe). The Belostomidae or giant water bugs, including the largest of North American Heteroptera, have strong, grasping forelegs and a stout beak which readily pierces the skin of man, making an aching, evidently envenomed wound. Notwithstanding these characteristics they do not escape the birds. Fifty-three species are on our list of captors, ducks, herons, and the like preponderating; in two cases, both herons, as many as 10 specimens were found in a stomach at one time. The Notonectidae again are sharply biting and exceedingly active under-water bugs; but the larger types are eaten by no fewer than 44 species of birds, sometimes in considerable number (30-57), while the little crawling and obscure *Plea* were identified in 60 stomachs of 12 species of birds, in numbers up to 40 in a single instance. The Gerridae, so very active on the water surface, fall a prey to at least 49 kinds of birds, sometimes being taken in considerable numbers (20-40). The Miridae or plant bugs are agile and rapid in their movements and of great variety in form and color, but corresponding with their abundance and wide distribution, we find them preyed upon by 108 species of birds. The Anthocoridae and Cimicidae, both odoriferous families, seem poorly represented in our tables, but from their habits we should hardly expect the latter to be found at all, while most Anthocoridae also live largely hidden lives. We have found Nabidae in the stomachs of 52 species of birds, Emesidae in 10, and Reduviidae in 115; these highly predatory forms therefore seem to have bird enemies about in proportion to their abundance.

There are only a few species of Pyrrhocoridae in the United States and none of them are abundant; hence the 18 captures by nine species of birds are perhaps not below proportion; while the relations of birds to the Lygaeidae shows again that an abundant and diversified group is sure to be frequently taken by a large variety of birds. In this family may be specially mentioned *Myodocha serripes*, a bug with an extraordinarily long neck, for what purpose is unknown; at any rate it is one of the most bizarre of the group in our area, but it is eaten by more than 20 species of birds and no fewer than 27 specimens have been found in a single stomach (purple martin). The large red and black *Lygaeus* species were taken by 14 species of birds, and the superabundant chinch bug (*Blissus leucopterus*), frequently observed in prodigious numbers, by 29. Three species of birds, the bobwhite, meadowlark, and brown thrasher, had records of a hundred or more chinch bugs at a meal. These facts contrast strongly with the state-

ment that "Very few birds prey upon it because of its repulsive smell and taste. It is questionable whether any of them are fond of it." (Garman, H., Bull. 74, Ky. Agr. Exp. Sta., p. 56, May, 1898.) In the series of Heteroptera composing the Coreidae and the groups aggregated as the Pentatomidae or Pentatomoidea, we have the typically stinking bugs. Practically all of them have powerfully scented secretions usually of a character obnoxious to man, but it is not evident that they are equally so to birds. Some of our Coreids (*Thasus*) are too large for most of our birds to prey upon, but those of the next rank in size are more or less freely taken, as *Acanthocephala* by 12 species, in numbers as high as 14-22 by Franklin's gull; and the various species of *Leptoglossus* by 16, 10-15 individuals at a meal by the same gull; Alydinae, nearly as large and equally smelly, are preyed upon by 21 kinds of birds. All Pentatomids are eaten so freely that it is difficult to pick the most representative examples. However, to begin, let us consider *Podisus*, a predacious, but nevertheless highly scented genus; it has been found in the stomachs of 29 species of birds, the most remarkable record being for a bird not included in these tabulations, namely a black duck collected in Maine, which had in its gullet alone 525 specimens of *Podisus sericeventris*.

One of the largest and most highly scented stink bugs of our fauna (*Acrosternum hilaris*) was found in the stomachs of 37 species of birds, in number up to 26 in one instance (purple martin), while for our typical and most abundant genus (*Euschistus*) 62 avian predators are known. The number of specimens found in a stomach exceeded 10 in a number of cases, and in one, that of a Franklin's gull, reached 175. The little Thyreocoridae, polished black with touches of yellow on the costa, were found in the stomachs of 65 kinds of birds, and the Scutelleridae in 60.

E. A. D'Abreu in his report on "Some insect prey of birds in the Central Provinces" [of India] (Rep. Proc. Third Ent. Meeting, Pusa, 1919, Vol. iii, p. 866, 1920) says "Pentatomids seem a favorite diet with birds." He gives notes also on bird enemies of 16 other families of Rhynchota.

The only report on the food habits of birds in the American Tropics, namely, the "Birds of Porto Rico" (Bull. 326, U. S. Dep. Agr., 1916), by Alexander Wetmore, in the accounts of the species throughout shows Hemiptera to be taken in due proportion.

The Cicadidae are chiefly large insects, a factor which to some extent must limit the number of their bird enemies; however the list here drawn upon shows 87 species and there are four records for one of our smallest birds, the house wren. Some of the larger birds

devour considerable numbers of the smaller cicadas, for example, 30 *Okanagana rimosa* were found in a nighthawk's stomach and from 19 to 41 *Tibicina septendecim* in each of several crow stomachs. It is of interest in this connection that adult as well as immature domestic fowls have been killed by crop-binding due to eating too many cicadas. (Weekly News Letter, U. S. Dep. Agr., vol. 6, no. 46, p. 14, June 18, 1919.) Wild birds, however, not only take large numbers of cicadas, but feed on them steadily day after day when the chance comes. The English sparrow and the crow blackbird are notable examples of this and it has been concluded by entomologists that broods of the periodical cicada issuing in parks and other places, where exposed to concentrated attacks of these species, are doomed to extinction. (Smith, J. B., Economic entomology, pp. 142-143, [1896]; Marlatt, C. L., Bull. 90, U. S. Dep. Agr., p. 10, 1894.)

Our records do not show whether any immature Cercopidae (spittle insects) are eaten by birds, but the adults are taken by 41 species. One chimney swift had eaten about 100 cercopids of the genus *Clastoptera*. Despite the numerous defenses they are said to have, Membracidae were eaten by no fewer than 136 species of birds represented in the present tabulation and in numbers up to 26 individuals in a single stomach. They have been found in 15 or more stomachs of each of the following species: Least, great-crested and ash-throated flycatchers, wood pewee, meadowlark, Brewer's blackbird, Bullock's oriole, English sparrow, cliff swallow, red-eyed, solitary, and warbling vireos, bush-tit, and ruby-crowned kinglet. The tree hoppers identified belong to 21 different genera, indicating that no partiality is shown. Membracids with the most prominent horns and spines of any in our fauna, such as those of the genera *Campylenchia, Platycotis, Thelia, Ceresa,* and *Platycentrus,* are taken with the rest. During stomach examinations 175 kinds of nearctic birds have yielded leafhoppers (Jassidae sens. lat.) and 10 or more stomachs of no fewer than 35 species have disclosed them. In a number of cases from 20 to 50 leafhoppers were found in single stomachs and in one case (barn swallow) a thousand.

The fulgorid fauna of the United States is scanty and our records of birds feeding on these insects correspond. Beyond the fact that they are well distributed through the various groups of the family and pertain to 18 species of birds, there is little of special interest concerning them. Some lesser yellow-legs had eaten from 50 to 400 each. The Psyllidae were found in the stomachs of 46 kinds of birds and the Aphididae in 86. Cases are known in which the

former have been devoured very extensively by birds, an entire orchard having been cleared of the pear psylla by nuthatches. (Zool. Bull. Pennsylvania Dep. Agr., vol. 3, p. 79, July, 1907.) Plant lice were found in large numbers in the stomachs of some birds, up to 200 or more in each of five species of the finch family, 300 or more in three of them (pine siskin and two goldfinches), about 650 in the stomach of a nighthawk and 1,600 in that of a wood duck. On a 200-acre farm in North Carolina, birds were found to be destroying more than a million grain aphids daily. (McAtee, W. L., Yearbook, U. S. Dep. Agr. (1912), pp. 397-404, 1913.) Aleurodidae have not as yet been identified from stomachs of nearctic birds; possibly some may have been confused with scale-insects. The latter, notwithstanding deprecatory statements that have been made relative to birds as predators upon them, have been found in the stomachs of 88 species of nearctic birds. No fewer than 100 *Eulecanium cerasifex* were found in the stomach of a rose-breasted grosbeak, 300 *Margarodes* in one of a scaled quail, 304 *Saissetia oleae* in that of a black-headed grosbeak and 200, 700, and 800 of the same scale, respectively, in three stomachs of the pine siskin.

Other enemies.—Salamanders, toads, and frogs are recorded in the Pennsylvania reports as feeding upon both Heteroptera and Homoptera, as are also the common swift lizard (*Sceloporus undulatus*) and the copperhead (*Agkistrodon contortrix*) and the hog-nosed snake (*Heterodon platirhinos*). The same source credits five species of turtles with eating Heteroptera and one with devouring Homoptera. Munz found that all the common frogs feed on Hemiptera about as freely as upon any other insects, and Garman found bugs in 6 out of 20 stomachs of the common toad. Winton reports the Texas horned lizard (*Phrynosoma cornutum*) as eating stink bugs.

Aquatic hemiptera, particularly Corixidae, are eaten by most freshwater fishes, while scattering representatives of the terrestrial families are taken now and then as opportunities occur. Forbes records from fish stomachs representatives of 14 families of Heteroptera and three of Homoptera. Among mammals, the common mole is known to take leafhoppers, chinch bugs, and other species; shrews do not entirely neglect Hemiptera; the nine-banded armadillo devours Cydnidae and Pentatomidae.

Insect enemies of Hemiptera include both nymphal and adult dragonflies, the former getting considerable numbers of Corixidae and the latter representatives of various families. Robber flies feed freely upon Hemiptera, ground beetles and ladybirds devour them, and the

Nyssonidae, Mimesidae, and Crabronidae, among predacious hymenoptera, prey more or less selectively upon Homoptera; in the eastern States a large Sphegid wasp is a special foe of cicadas. Other enemies of cicadas include dragonflies, wasps, predatory beetles and bugs, mantids, spiders, mites, hymenopterous and dipterous parasites, fishes, snakes, turtles, squirrels, badgers, armadillos, skunks, moles, and fungi. Spiders consume many Hemiptera of a wide variety and are credited with being among the most important natural enemies of leafhoppers. The latter insects are heavily parasitized by the *Dryinidae,* and by at least five other families of Hymenoptera, by *Pipunculidae,* and Strepsiptera; and are preyed upon by larvae of Chrysopidae, and by Coccinellidae, Reduviidae, and certain other insects.

The Pyrrhocoridae said to be specially protected are preyed upon by spiders, pseudoscorpions, thrips (the eggs), tachinid flies, reduviid bugs, and lizards. The Coreidae have special parasitic foes among the Tachinidae; while the order of Rhynchota in general is subject to hymenopterous parasites, the abundance of plant lice and scale insects in particular depending to a large degree in many cases upon the relative numbers of these destructive foes. Lycaenid caterpillars feed upon aphids, coccids, jassids, and membracids. A page would scarcely suffice to list the numerous enemies of plant lice which include, besides parasites, coccinellid, lampyrid, syrphid, hemerobiid, and chrysopid larvae, in addition to adult ladybird beetles, assassin bugs, and other insects, mites, and spiders. Fungi are known to destroy, at times, large numbers of hemiptera, among which may be mentioned plant lice, scale insects, mealybugs, and the chinch bug.

Discussion.—Despite their malodorous secretions and other "protective devices" there can be no doubt that Rhynchota are taken fully in proportion to their abundance by nearctic birds, and the evidence is that their other enemies are numerous and effective. If we consider the most pronouncedly repugnant species found in the United States, such as the harlequin bug (*Murgantia histrionica*) and the squash bug (*Anasa tristis*),[1] we find that severe infestations of the former have been kept in check by English sparrows (Sherman, F., Bull. North Carolina Dep. Agr., vol. 32, no. 7, p. 21, July, 1911) and that the squash bug has a number of deadly enemies. It has been shown that the volatilized secretions of squash bugs if confined in a glass container are capable of killing toads (Weed and Conradi, Bull. 89, New

[1] It is worth noting that of these two common and exceedingly malodorous bugs, one is warningly, one obscurely colored. Where is the correlation that theories as to warning colors demand?

Hampshire Agr. Exp. Sta., pp. 21-23, Feb., 1902), and the conclusion was drawn that "toads do not ordinarily devour many of these pests." Perhaps they do not "devour many" of them, nor, with the whole insect world available for them to prey upon, should they be expected to specialize upon squash bugs, but they do eat them, as found by Kirkland (Bull. 46, Hatch Exp. Sta., p. 26, 1897) and also by Biological Survey investigators. Bird enemies also are not lacking, present records showing six species of birds known to feed upon *Anasa tristis* and four upon other species of the genus. The harlequin bug is sometimes heavily parasitized also, while the squash bug has both tachinid and hymenopterous parasites and is subject to a bacterial disease.

Disregarding the "protective adaptations" and reasoning alone from the prevalence of hemiptera, there would be no presumption that these insects would constitute a tenth of the food of any species of birds, yet they actually do contribute 10 per cent or more of the subsistence of the following 12 species in the United States: Nuttall woodpecker (number of stomachs examined 53), percentage of Rhynchota in the food, 14.76 per cent; Scissor-tailed flycatcher (129), 10.17 per cent; eastern phoebe (370), 10.38 per cent; black phoebe (344), 10.56 per cent; crested flycatcher (265), 14.26 per cent; least flycatcher (177), 11.12 per cent; Bullock's oriole (162), 10 per cent; sharp-tailed sparrow (51), 12 per cent; spotted towhee (139), 14 per cent; purple martin (205), 14.58 per cent; barn swallow (467), 15.1 per cent; and rough-winged swallow (136), 14.9 per cent; more than 20 per cent of the food of two birds, namely the black-headed grosbeak (225), 21 per cent, and cliff swallow (375), 26.32 per cent, and more than 30 per cent of the total diet of the violet-green swallow (110), 35.96 per cent.

If the glandular secretions of hemiptera had the repugnatorial, not to say dangerous, qualities attributed to them, there would be no such wholesale preying upon them as is shown in the foregoing data. Descending to milder forms of "protection" as afforded by pointed protuberances and secretions of wax, we find that the "hardihood" of birds (from the selectionist point of view), or in other words their tendency not to be bound by human criteria, is so great that such devices simply do not count.

NEUROPTEROIDEA (DOBSONFLIES, SNAKEFLIES, SCORPIONFLIES, ANT-LIONS, CADDISFLIES)

In the period during which the records of bird food here discussed were obtained, the conception of the group of insects broadly termed Neuroptera has gradually evolved from that of a catch-all for net-

veined insects to a restricted group of very few families. Hence many of the determinations (in want of re-examination) cannot be definitely correlated with modern classification. With little doubt, therefore, there has been confusion of records between Neuropteroidea (in the present sense) and some of the orders elsewhere discussed as Agnatha, Mecaptera, and especially Plecoptera. Hence the tabulation figures given are only approximations, and a better conception of the relations of birds to the insects would be obtained by lumping all of the so-called net-veined insects together.

Protective adaptations.—The Neuropteroidea have not been given so much attention by adaptationists as some other groups of insects, but certain supposedly protective features have been pointed out or are suggested by analogy with other described cases. Dobsonflies are large, the larvae and females have powerful biting-jaws, while in some cases the males have enormously developed mandibles of less sturdy construction, and the coloration of the wings of some presents strong contrasts. The latter characteristic is possessed by the Myrmeleonidae also, while their larvae, the ant-lions, have large, strong jaws and an antlike odor. Some Ascalaphidae are said to resemble dragonflies both in appearance and habits; Chrysopidae have vile smells earning them the name of stink flies; and Mantispidae not only have predatory forelegs but are said to be protected by their resemblance to Hymenoptera. (Poulton, E. B., Trans. Ent. Soc. London, 1902, p. 536.) "The well-known cases of Caddice-worms (Trichoptera) are partly for concealment and partly for defence." (Poulton, Colours of Animals, p. 77, 1890.) Some of them resemble snail-shells.

Bird enemies.—While Neuroptera (sens. lat.) have been identified from the stomachs of 56 species of birds there is little object in discussing further this heterogenous assemblage. Sialidae (dobsonflies etc.), despite their average large size and biting powers, were taken by 38 kinds of birds; 58 specimens were found in the stomach of a Bonaparte's gull and from 55 to 93 larvae in three stomachs of lesser scaups and 192 in one of a canvas-back. Snakeflies, of bizarre appearance, and of limited distribution in the United States were identified in the food of 22 species of birds; and Mantispidae, "protected by their resemblance to Hymenoptera," and also by considerable rarity in our fauna, were found in the stomach of 11 species. Stink flies (Chrysopidae) were eaten by 18 kinds of birds, and Myrmeleonidae by 20. *Ascalaphus* was identified but once, quite in keeping with its extreme rarity, and Hemerobiidae 11 times. The figures for identifications are low for scarce or locally distributed groups, but

when we come to one of common and general occurrence, the corresponding rise in frequency of capture by birds is apparent at once. The caddisflies, more numerous in species and individuals than all our other Neuropteroidea together, appropriately contribute nearly two-thirds of the total number of records for the group. The number of species of birds feeding upon them is 113, and of these 45 or more had taken the "specially protected" larvae. The number of records of caddisflies determined was 10 or more for 23 species of birds, and more than 20, 30, and 40 in the case of four, three, and three species respectively. The number of specimens taken by single birds exceeded 30 of larvae in a number of instances and ran as high as 207 (in a scaup duck), and of adults reached such figures as 280 and 400 in the case of the nighthawk.

Identifications of Neuropteroidea

Group	Number of identifications	Percentage of identifications among those of all Neuropteroidea	Percentage of species in this group among the whole number of nearctic Neuropteroidea [1]
Neuroptera (sens. lat.)	119	9.0564	...
Megaloptera	167	12.7094	3.5648
Rhapidioidea	54	4.1096	1.6886
Neuroptera (sens. str.)	108	8.2192	32.2706
Phryganoidea	866	65.9061	62.4774
All Neuropteroidea	1,314		

Other enemies.—Forbes reports that neuropteroid larvae compose about 10 per cent of the food of the sucker and catfish families in Illinois; he found caddis larvae in the stomachs of 17 species of fishes. According to various authors, these larvae are an important element in the food of most kinds of trout. Salamanders, frogs, larvae of stoneflies, and parasitic hymenoptera also are enumerated among the enemies of caddis larvae. Forbes found larvae of Sialidae in seven species of fishes, and these are known to be eaten also by frogs and turtles. Chrysopidae have been seen to be eaten by frogs, salamanders, and ants, and they have numerous hymenopterous parasites sometimes destroying inmates of about half of the cocoons. (McGregor, E. A., Can. Ent., vol. 46, pp. 306-308, 1914.) Frogs are recorded also as capturing Mecaptera, as are also lizards and larvae of ant-lions. Robber flies and dragonflies apparently devour any Neuroptera chance throws their way.

[1] Computed from Banks, Nathan, Catalogue of neuropteroid insects (except Odonata) of the United States, 53 pp., 1907.

Discussion.—It is obvious from the available data on enemies of Neuropteroidea that the small or rare groups have few, the large and abundant families many foes, the result that would be predicted with "protective adaptations" discounted. The group most numerous in species and individuals, namely the caddisflies, has the most enemies, and their larvae, said to be well defended from enemies, form one of the staple elements of the food of fresh-water fishes all over the globe, as well as a favorite prey of aquatic birds.

LEPIDOPTERA (MOTHS, BUTTERFLIES)

Protective adaptations.—In the space that can be devoted in this paper to protective adaptations of Lepidoptera it is impossible to do more than call attention to general aspects of theoretical considerations, since what has been written on the subject would fill many volumes. This flood of literature is due principally to the fact that Lepidoptera have been regarded as the chief examples of the phenomena of warning colors and of mimicry, subjects that have been expounded and discussed at great length.

Warning coloration, it need hardly be stated, designates the conspicuous, often highly contrasted, patterns, which it is held may be assumed with relative impunity by tough, distasteful, or dangerous species. Batesian mimicry is the more or less pronounced resemblance to these species by others supposedly less qualified to cope with the struggle for existence, while Mullerian mimicry is mutual approach in appearance by species all of which belong to "specially protected" groups. As remarked in my 1912 paper, these theories were chiefly built up at a time when there was almost complete ignorance of the actual feeding habits of predacious animals, and attempts to secure evidence on the subject by experiment were in most cases characterized by a singular lack of appreciation of the vital factors involved and of realities in nature.

The following statement by Alfred Russell Wallace gives the gist of the principal nearctic instances of mimicry among Lepidoptera: "In North America, the large and handsome *Danais archippus* with rich reddish-brown wings is very common, and it is closely imitated by *Limenitis misippus,* a butterfly . . . . which has acquired a color quite distinct from that of the great bulk of its allies. In the same country there is a more interesting case. The beautiful dark bronzy-green butterfly, *Papilio philenor,* is inedible both in larva and perfect insect, and it is mimicked by the equally dark *Limenitis ursula.* There is also in the Southern and Western States a dark female form of the

yellow *Papilio turnus*, which in all probability obtains protection from its general resemblance to *P. philenor*." (Darwinism, p. 248, 1896.)

Mimicry of another order of insects, the Hymenoptera, is shown by many of the clear-winged moths (Syntomidae and Sesiidae) as adults; and of black-and-yellow ringed larvae, it is said they gain great advantages from resemblance to the justly respected appearance of hornets and wasps.

The majority of adults of Lepidoptera, especially the moths, exhibit in greater or less perfection what is called cryptic coloration, that is resemblance to details of the environment, exemplified by the species that are inconspicuous on bark, old leaves and the like. This style of protective adaptation also is attributed to many larvae and pupae. On this topic Poulton says: "There is no better instance of special protective resemblance than that afforded by the larvae of Geometrae, 'stick caterpillars' or loopers as they are often called. These caterpillars are extremely common and between two and three hundred species are found in this country [Great Britain]; but the great majority are rarely seen because of their perfect resemblance to the twigs of the plants upon which they feed." (Poulton, E. B., The colours of animals, p. 26, 1890.)

This idea is pushed to an extreme by another author as shown by the following quotation relating to the caterpillar of "a geometrid moth. In the larval state the insect bears a very close resemblance to a twig. Its habit of clinging to a real twig with its posterior 'legs' and allowing the body to swing out, adds to the illusion. The head of the caterpillar resembles a leaf bud, while in color the entire creature is an exact counterpart of a rough apple twig, the plant upon which it naturally feeds. Thus complete immunity is secured from the attacks of birds and all enemies which depend chiefly upon sight."[1] (Howes, Paul Griswold, Insect behavior, pp. 164-165, 1919.)

Adaptations of caterpillars supposed to repel enemies, which have received the most attention from writers on the subject, include: armatures of hairs or spines, repugnant odors, warning colors, and terrifying attitudes, in addition to various special resemblances. Among the latter, Howes considers especially remarkable those that "rely for their protection upon their mimicry of the excreta of birds. I have been completely fooled by these larvae on more than one occasion. They frequently rest in the center of a green leaf and while conspicuous, never suggest a living insect to the uninitiated. In color, the upper and lower portions of the body are dark chocolate brown.

[1] See pages 56 and 85 for the facts as to immunity of loopers.

banded through the center with pure white, which suggests the lime so often seen in the excreta of birds. The entire creature is highly glossed, which gives a fresh and moist appearance to the object, which makes no attempt to conceal itself, depending entirely upon its strangely camouflaged body for protection." (Insect behavior, p. 165, 1919.) [1]

Poulton summarizes the purpose of caterpillar adaptations as follows: "In the remarkable abundance and variety of methods by which concealment is effected in Lepidopterous larvae, we probably see a result of their peculiarly defenceless condition. . . . . Hence larvae are so colored as to avoid detection or to warn of some unpleasant attribute, the object in both cases being the same—to leave the larva untouched, a touch being practically fatal." (The colours of animals, p. 51, 1890.)

On the concealment of lepidopterous pupae, the same author says: "Protective Resemblance, either Special or General, is seen in nearly all exposed pupae, but most chrysalides are buried in the earth or protected by cocoons. The cocoons are often sufficient defense, because the silk is very unpleasant in the mouth; but such protection only applies in the warmer weather when there is an abundance of insect food. In the winter, insectivorous animals are pinched by hunger, and would devour the pupa in spite of the cocoon. We therefore find that all cocoons which contain pupae during the winter are well concealed, either spun between leaves which fall off and become brown, or hidden under bark or moss, or constructed on the surface of bark with a color and texture which renders them extremely difficult to detect." (Op. cit., pp. 51-52.)

Pausing only long enough to note the incorrectness of the statement "all cocoons which contain pupae during the winter are well concealed" (witness those of Saturniidae, not to speak of the cases of many Tineidae), we may pass to Howes' more imaginative account.

We find, for instance, the chrysalis of a butterfly, a species of Vanessa. It hangs by a tiny silk-fastened stem under a protecting fence rail. Within the shell of the chrysalis, there is nothing but a mass of disintegrating tissues, a thick fluid, studded with globules of fat. It is neither caterpillar nor butterfly. It cannot thrash about from side to side or make a demonstration, there are no spines to pierce a would-be enemy, no wings by which the creature might take flight. It is as helpless now as so much custard, for the insect is in the process of change from one form to another.

[1] This comment ignores the fact that a great many birds habitually devour the excreta of their young, even returning to it when accidentally dropped, and this nestling excreta is exactly of the luscious appearance described by Howes.

Such is the actual condition of the pupal butterfly, but let us examine its outer covering. It is a frightful-looking object, armored, and covered with sharp spikes between which beady false eyes peer out. It is absolutely harmless but appears otherwise. To birds it is doubtless a thing to beware of, yet one tiny puncture of its brittle covering would reveal a delicious feast within.

Many insects are thus protected, ones that could not compete in any form of battle. They are given immunity from attack because they could not ward it off themselves. In the case of the transforming pupa, some such form of protection becomes a necessity. A butterfly in the making is as helpless as the egg from which it sprung, so Nature resorts to camouflage to terrorize the destroyers of her children. (Insect behavior, p. 168, 1919.)

Aside from the fact that *Vanessa* pupae do not enjoy immunity (see p. 62), we may well inquire whether birds are not Nature's children just as much as the butterflies, and just as fully entitled to be her beneficiaries?

Bird enemies.—Identification to species especially has lagged more in the case of lepidopterous items of food, than in those of any of the other larger orders of insects, due chiefly to poor condition of the remains of adults, and to lack of knowledge of larvae. Unidentified Lepidoptera exceed 2.85 times those in some degree identified, and in considering the relation of the percentages of identifications to those of the number of species of various groups, the former figures should be multiplied by 2.85.

In view of the very unsatisfactory distribution of identifications of Lepidoptera to families (over 70 per cent of the whole number being merely as Lepidoptera), it would be of little avail to discuss the relative importance of family groups as bird food. Rather it will be better to treat the subject along lines of general interest already developed, as the preference between larval and adult Lepidoptera, the extent to which hairy caterpillars are eaten, and the relation of birds to butterflies, the chief illustrations of mimicry theories.

The question as to which is eaten most extensively, adult or larval Lepidoptera, is easily answered in favor of the latter. As the table shows 68 per cent of all records of Lepidoptera are for larvae, further unidentified; moreover, it is certain that the great bulk of specimens identified to families also were larvae. Thus the Noctuidae determined were chiefly cutworms, the Geometridae were mostly loopers, the Tineidae principally case-bearers, and so on. Caterpillars, not further identified, were found from 50 to 100 times in the stomachs of 23 species of birds; from 100 to 200 times in 21 species; from 200 to 300 times in eight species (downy woodpecker, blue jay, red-winged and Brewer's blackbirds, warbling vireo, black-capped chickadee, hermit thrush, and bluebird); from 300 to 400 times in two species

Identifications of Lepidoptera

Family	Number of identifications	Percentage of identifications among all Lepidoptera	Percentage of species in this family among described nearctic species of Lepidoptera [1]
Tineidae	499	.2098	6.3575
Elachistidae	5	.0021	2.9296
Gelechiidae	5	.0021	4.4548
Tortricidae	149	.0626	7.2183
Crambidae	17	.0071	...
Pyralidae	38	.0160	10.0573
Sesiidae	2	.0008	1.5252
Cossidae	5	.0021	.3171
Cochlidiidae	2	.0008	.4983
Psychidae	2	.0008	.1963
Geometridae	87	.0366	12.2318
Bombycidae	6	.0025	.0151
Lasicampidae	174	.0731	.3624
Liparidae	7	.0029	.2265
Notodontidae	118	.0496	1.2533
Noctuidae	1,128	.4742	32.1049
Agaristidae	4	.0017	.2265
Arctiidae	68	.0286	1.7668
Ceratocampidae	66	.0277	.1812
Saturniidae	29	.0122	.4681
Sphingidae	156	.0656	1.2533
Moths (further unidentified)	2,116	.8896	...
All moths	*4,683*	*1.9685*	*90.1541*
Hesperiidae	9	.0038	2.9447
Lymnadidae	1	.0004	.0453
Nymphalidae	59	.0248	2.5218
Pieridae	1	.0004	.9664
Papilionidae	2	.0008	.3171
Butterflies (further unidentified)	41	.0172	...
All butterflies	*113*	*.0474*	*9.8459*
Lepidopterous eggs	134	.4233	...
Lepidopterous larvae	12,676	5.3291	...
Lepidopterous cocoons and chrysalides	227	.0954	...
Lepidopterous adults	654	.2749	...

[1] Computed from Dyar, H. G., A list of North American Lepidoptera, etc., U. S. Nat. Mus. Bull. 52, 723 pp., 1902.

(red-eyed vireo and robin); and more than 400 times in the following five species: crow (438), starling (727), meadowlark (474), crow blackbird (600), and English sparrow (466). One hundred or more caterpillars further unidentified were found in single stomach contents of each of the following birds: sparrow hawk, downy woodpecker, hairy woodpecker, black-billed cuckoo, yellow-billed cuckoo, crow, starling, crow blackbird, hermit thrush, wood thrush, and robin. A very characteristic phase of the destruction of caterpillars by birds is their use as a special food for the young; numerous species of birds make a practice of feeding the young a very much higher proportion of caterpillars than is taken by the adults.

It has often been asserted that hairs and spines are very effective in protecting certain caterpillars from birds.[1] Bastin for instance, states that "stinging hairs defend their possessors from almost all birds except the cuckoos." (Insects, their life-histories and habits, p. 168, 1913.) These claims ignore the fact that birds are very well equipped with relatively insensitive bills and feet for removing spines and hairs from larvae if they choose. Some birds do this, others actually dissect caterpillars, eating parts they want from the inside, piecemeal. Hairy and spiny armature is no bar to birds with such feeding habits, and, furthermore, do not seem to be of any great service in relation to numerous birds which swallow entire larvae thus defended. A characteristic statement about hairy caterpillars is: "Tent caterpillars have few enemies. . . . . Our two species of Cuckoos make it a regular business to feed upon these worms which no other birds will eat." (Lugger, Otto, Fourth Ann. Rep. Ent. Minn. (1898), p. 142, 1899.)

Seventeen of the species of birds included in the tabulations on which this paper is based had eaten tent caterpillars or the eggs from which they hatch; numbers of larvae taken at a meal ran up as high as 200 in case of the black-billed cuckoo, and of eggs as high as 1,047 in that of a blue jay. Compiling records from the reports of entomologists and others who have found birds feeding upon tent caterpillars, we get a list of 43 species of bird predators upon the so-called "Orchard" species (*Malacosoma americana*) and 32 upon the "Forest" species (*M. disstria*). Caterpillars even more offensively

[1] In the case of this as in other similar claims, we may well ask why such theoretically effective defenses have not been developed by a larger proportion or in fact by all larvae? The most cursory consideration of the subject shows that hairiness of caterpillars is in the main a phyletic character. A few related families include the great bulk of the hairy larvae.

hairy than these are those of the gipsy and the brown-tailed moths; the hairs of the latter species especially cause a troublesome and painful rash upon the skin of man. Nevertheless 46 kinds of birds are known to eat caterpillars of the former species and 31 those of the latter. (For a valuable article on bird enemies of these and other hairy caterpillars, see Forbush, E. H., Bull. 20, n. s., U. S. Div. Ent., pp. 85-93, 1899.)

The larvae of the tussock moth (*Orgyia leucostigma*) are supposed to be especially distasteful to birds, but Forbush records (Mass. Crop Rep., July, 1900, p. 36) nine species of birds as feeding upon them. The writer has observed English sparrows and robins eating them; in the spring of 1921 in Washington, D. C., the larvae were quite common and robins were feeding freely upon them, carrying them to their young, I believe, as it was a common sight to see the birds flying with the white tufts showing at the tips of their bills.

Again records of birds feeding on fall webworms (*Hyphantria textor*) are relatively scanty, only six species being named, yet careful observation in the field has proved one of them to be a very effective foe. Dr. C. Gordon Hewitt informs us that of the various factors operating in the reduction of this insect in Nova Scotia in 1916, the red-eyed vireo was most important and "it was estimated that about 40 per cent of the larvae had been destroyed in the webs by this bird." (Rep. Dominion Ent. 1917, p. 8.) A later report shows an average destruction of 68 per cent.

It would not be necessary to refer to the preying of birds upon smooth caterpillars, a thing universally done, except for theoretical disquisitions as to the "protected nature" of certain groups. The Geometridae, loopers or measuring worms, are said to be protected by resemblance to twigs, etc., a statement made without giving due weight to the fact that such a defense depends upon immobility whereas these caterpillars must be in motion the greater part of the time while searching for and devouring food. Forty-four species of birds are recorded as feeding upon Geometridae in our tabulation and numbers of specimens as high as 20 were taken at one meal by the starling and 90 by the robin.

Larvae of the Sphingidae are said to be protected by their "horns" and by "terrifying attitudes," but 44 species of birds covered by the present investigation do not seem to agree with the theorists on these points. Ten species are known to prey upon *Dielephila lineata* alone, and in field observation the crow has been known to clear tomato patches of the hornworm (*Phlegethontius sexta*).

Many printed pages have been devoted to discussion of the question: "Do birds eat butterflies?" but the natural answer: "Certainly, but probably not out of proportion to their abundance," seems not to have occurred to the disputants.

At this point it will be well to say a word about the alleged difficulty of identifying adult Lepidoptera, especially butterflies in the stomach contents of birds. But for this, some argue, the number of records of butterflies eaten would be much larger. The assumption is made that the scales are necessary to identification, and since they are so easily rubbed off, determination will usually be impossible. This objection serves mainly to exhibit the ignorance of its proposers relative to the analysis of the contents of bird stomachs. In the first place when adult Lepidoptera have been eaten at all recently, that fact is evident to the practiced eye, even unaided, on first glance at the stomach contents. A characteristic fuzzy, felted appearance, due to the distribution of the hundreds of scales throughout the mass, tells the tale at once. Even after digestion is far advanced the scales do not disappear because they are so numerous and stick to everything, and they are evident under magnifications used in the analysis of practically every stomach contents. Moreover were all scales absent, it would be possible to unroll the wing membrane, if swallowed, and examine the venation; the antennae also would usually be present; and the form of the head, thorax, and body, which are characteristic, could be made out.

In addition we would remind the reader that all things found in birds' stomachs are not ground to a powder. Just the reverse in fact is true; birds feed more or less constantly, and whenever shot they will as a rule just have swallowed some article of food which, of course, will be in good condition for study. In the long run all constituents of the food will be found nearly or quite intact in the stomachs in proportion to the frequency in which they are taken.

However it is unnecessary to discuss the matter further. One need only consider the extent to which we have identified certain insects far more fragile than butterflies, as mayflies (Ephemeridae) 484 records, midges (Chironomidae) 1,003 records, and crane flies (Tipulidae) 1,565 records, to be assured that there is no likelihood whatever of a butterfly being overlooked during careful stomach analysis.

Of the 113 records of birds eating Rhopalocera included in the present tabulations, 24 refer to larvae and two to chrysalides. It is worth noting that one of the larval records was for *Anosia plexippus*, two for *Papilio* species, and six for *Vanessa* species, supposedly the

best protected forms. Nymphalidae and Hesperiidae are most numerously represented among the adults taken.

The 87 records of imago butterflies are distributed among 15 species of birds, but all save 18 of them pertain to a single bird, the pigeon hawk. The specimens of this hawk examined were taken on their southward migration at a point that is in the migration path of butterflies also, so that opportunities for catching these insects were at the best. (It is worth noting here that dragonflies, swallows, swifts, and bats also using this same migration track were preyed upon by the pigeon hawk.) In this case as in many others the abundance and availability of prey is shown to have great influence upon the choice of food by birds. Amid the butterflies, this hawk preyed upon them; elsewhere we have no record of its doing so. Clearly the other birds (14 species) in whose stomachs butterflies have been found (18 records) are only occasional predators upon them. This is only what would be expected, for ordinarily butterflies, numerically, are no considerable part of the insect fauna; when under extraordinary circumstances they do become over-abundant they are more frequently devoured by birds. Thus Bryant found Brewer's blackbird eating large numbers, and three other species of birds smaller numbers, of *Eugonia californica* during an unusual outbreak of the species. (Condor, vol. 13, pp. 195-208, Nov. 1911.)

Summary of identifications of Lepidoptera: Total number 18,487; percentage of identifications among those of all insects, 9.6831; percentage of species in this group among the whole number of insect species, 15.6180.

Other enemies.—For the most part fishes are only casual devourers of Lepidoptera, getting chiefly larvae which fall into the water, most of which would perish anyway. However, gamy fishes such as trout snap up adults that incautiously fly near the surface of the water.

Bullfrogs have been observed feeding freely on *Papilio turnus* adults (Mallonee, Science, 1916, pp. 386-387) and half a dozen leopard frogs have been noted as eating 500 *Argynnis aphrodite* in a week (Shiras, Nat. Geogr. Mag., 1921, p. 174). Kirkland found cutworms, tent and other caterpillars to compose 28 per cent of the total food of 149 toad stomachs examined by him, and Munz found lepidopterous larvae in stomachs of four species of frogs. In 209 leopard frogs, Drake found one imago, one chrysalid, and 121 larvae of Lepidoptera. Surface reports remains of Lepidoptera in stomachs of eight species of salamanders, one toad, and nine frogs. In the Tropics lizards are said to be important enemies of adults of this order and our lizards

are known to eat both larvae and imagos. Surface records Lepidoptera from the stomachs of five species each of snakes and turtles.

Cutworms are commonly taken and other caterpillars and chrysalides are devoured to a smaller extent by moles. A number of small mammals, such as opossums, spermophiles, ground squirrels, tree squirrels, prairiedogs, grasshopper mice, skunks, raccoons, shrews, armadillos, the mongoose, and *Nasua* feed more or less regularly on caterpillars, and take an occasional pupa or imago. Bird has observed that field mice and skunks are effective enemies of the gall-making larvae of *Papaipema*. (Can. Ent., vol. 41, no. 2, pp. 67-68, Feb., 1909.) Haskin has reported squirrels devouring large numbers of *Melitaea chalcedon* adults (Ent. News, vol. 27, no. 8, p. 370, Oct., 1916), and Attwater found wings of several hundred *Danais archippus* that had been eaten by the Texas grasshopper mouse (Bull. Amer. Mus. Nat. Hist., vol. 6, p. 181, 1894). Bats catch moths, and monkeys also have been reported as eating butterflies commonly. (Trans. Ent. Soc. London, 1912, p. iv, xvii-xviii.)

The insect enemies of Lepidoptera also are numerous and some of them are exceedingly destructive. Robber flies and dragonflies are frequently observed devouring adult Lepidoptera, and a Natal collector considers Mantidae the chief enemies of butterflies. (Proc. Ent. Soc. London, 1906, p. lii.) Spiders catch them directly or trap them in their webs, Phymatidae lie in wait for them, and predacious beetles sometimes capture them. However, the latter predators are more serious foes of caterpillars, in the pursuit of which they have as fellows numerous wasps. Ants, chrysopid larvae, and other insects and mites feed upon the eggs; and parasites often destroy large proportions of the eggs laid. Parasites of lepidopterous larvae also are legion, including numerous species of Hymenoptera and Diptera, and they take a large toll from every generation of the insects. Exceedingly high percentages of parasitism have frequently been observed, reaching locally in a few cases even to 75 and 100 per cent. It has been found in one case at least that no fewer than 63 species of hymenopterous parasites attack a single species of moth. (Cambridge Nat. Hist., vol. 5, p. 521, 1910.)

Bacterial diseases frequently kill large numbers of caterpillars and sometimes locally extirpate certain species.

Discussion.—It is one thing to record a proved fact, but quite another to assert that a certain thing does not occur in nature. Our stock of verified data stands as an imperishable record and addition to it, not subtraction, is the rule. Let none be tempted therefore to add

to the vast body of speculation that has proceeded from slight premises by data in a preceding paragraph apparently indicating that birds do not eat many chrysalides of butterflies. For in that case we must refer him to Bryant's statement that about 15 per cent of the pupae of *Eugonia californica* at a time when they were very abundant showed evidences of attack by birds (Condor, vol. 13, p. 200, Nov., 1911), and to Chittenden's that "in one case it was found that during the winter the number of pupae of the cabbage butterflies was reduced more than 90 per cent by birds feeding upon them." (Farmers' Bull. 766, U. S. Dep. Agr., p. 9, 1916.)

In this paper we cannot possibly discuss all of the data relating to predators upon insects and other animals, but the evidence we present in our tabulations surely goes far to prove that no groups are neglected by predators (except as availability or sheer size dictates) and that the various groups are preyed upon more or less in proportion to their numbers. As applied to Lepidoptera this rule is apparent in the greater number of records for such large families as the Noctuidae, Tineidae, and Tortricidae for instance as contrasted to such smaller ones as the Sphingidae, Arctiidae, and Bombycidae or of the more numerous Nymphalidae to the less numerous Papilionidae. Due to the high proportion of unidentified Lepidoptera, our tables are not as complete and informing as could be desired, but where there are apparent exceptions to the rule of proportional loss to predators, data from other sources usually indicates unreliability of the apparently negative evidence. For instance the records of Geometridae in our table seem too low for this rather important family which is undoubtedly numerous in individuals. But that this is due solely to the make-up of our material is proved at once by reference to the literature; no fewer than 73 species of nearctic birds have been observed feeding on cankerworms (*Paleacrita* and *Alsophila*) for instance. Wellhouse, who reports finding cankerworms in 98 of 100 stomachs of birds (36 species) collected near Lawrence, Kans., in 34 of which they composed the total food, says: "Probably no insect is a favorite food of more species of birds than the cankerworm larva." (Bull. Univ. Kansas, vol. 18, no. 1, p. 301, Oct. 1917.) In a study of birds in relation to cankerworms in Illinois, Forbes found these larvae to compose 45 per cent of the food of a collection of 55 birds (15 species) and that one species, the cedarbird, was destroying them at the rate of at least 90,000 per month. (Forbes, S. A., Trans. Illinois State Hort. Soc. (1881), pp. 123-130, 1882.)

The snow-white linden moth (*Ennomos subsignarius*) has a typical twiglike caterpillar, but several entomologists have testified that it was practically exterminated in cities by the English sparrow. (See Herrick, G. W., Bull. 286, Cornell Univ. Agr. Exp. Sta., p. 62, Nov., 1910.)

The only other important family of moths which our tabulations might indicate to be neglected by birds is the Pyralidae. With little doubt this condition is due either to the larvae not being recognized or to our stomach material not being fully representative. Certainly birds are known to be enemies of our pyralid larvae, a little search revealing records of avian predators upon *Loxostege similalis*, *L. sticticalis*, *Pilocrocis tripunctata*, *Pinipestis zimmermanni*, *Diatraea saccharalis*, *Acrobasis nebulella*, and *Pyrausta nubilalis*. Five species are known to feed on the last-named, the corn rootborer, while of *Loxostege sticticalis*, the beet webworm, it is recorded that: "Insect-eating birds devour the worms in large quantities. Where the worms were abundant [in Colorado] . . . . blackbirds were attracted in flocks of thousands and in several instances . . . . the worms were all cleaned out of fields by them in the course of two or three days." (Gillette, C. P., Bull. 98, Colorado Agr. Exp. Sta., p. 10, Mar., 1905.)

These instances emphasize the universal scope of the predatory activities of birds; in general the enemies of economic species of insects are better known, and fully discounting the fact that they are most studied, this is only another way of saying that the most abundant species have the most numerous enemies.

COLEOPTERA (BEETLES)

Protective adaptations.—While more pages have been written about warning colors, mimicry and the like in Lepidoptera, which insects furnished the inspiration for this line of speculation, the important and extensive order of Coleoptera has been far from neglected and perhaps the most positive statements of all have been made regarding the "protected" status of some of its members. In conclusions derived from G. A. K. Marshall's data on "The Bionomics of South African Insects" (Trans. Ent. Soc. London, 1902, pp. 393-584), Prof. E. B. Poulton in discussing the chief specially defended Coleoptera mentions: "The groups about which there seems to be no doubt at all—conspicuous, constantly refused by insect-eaters, and liable to be mimicked by other Coleoptera are the following: Erotylidae, Coccinellidae, Malacodermidae, including the Lycinae, Lampyrinae and Telephorinae, Melyridae, Cantharidae, Chrysomelidae,

Endomychidae, and Pyrochroidae." The Cleridae are cited as a family that while undoubtedly distasteful, in forming color associations take the colors and patterns of other insects "rather than impress the stamp of their own likeness on the assemblage." The following four families are said to be "at any rate partially distasteful": Scarabaeidae, Cetoniidae, Tenebrionidae, and Lagriidae. The longicorns are thought to include a few distasteful species in addition to many that mimic aculeate Hymenoptera and other specially defended insects. Cicindelidae are said by Wallace to be protected by cryptic coloration, the refuge of the weak, while Poulton and Shelford have recorded them as models mimicked by species less prepared for the struggle for existence—a tribute to the strong.

"The Carabidae are a powerful specially defended group," writes Poulton (op. cit., pp. 513-514) "and it is of advantage to be recognized as belonging to the group, even though it is no doubt of still greater advantage to be mistaken, as may happen at a distance, or on a superficial view, or during rapid movement, for the still more formidable Mutillidae and ants" . . . . . "Dr. A. R. Wallace has always thought that the extreme hardness of the mimicked Curculionidae and Anthribidae is the character which protects them." (Poulton, op. cit., pp. 522-523.)

Comment of this kind could be cited indefinitely, for something or other has been claimed to be "special protection" for practically every group of beetles. It is undesirable and unnecessary to cite this matter in detail, but some attention should be given to the subject of repugnatorial secretions which has figured considerably in accounts of protective adaptations of beetles. For convenience, a summary of the occurrence of such secretions is quoted from a recent article on the topic:

"It has been well understood that the presence of defensive or repugnatorial scent glands in certain insects exists in direct adaptation to the needs and habits of their owners and in close response to their environment; also that such glands are of very frequent occurrence and with much variation as to position, form, and function; and that their presence is of value to the insect for repellent, defensive and warning purposes. . . . . Biologically speaking, the principle involved in such cases, though often modified, is practically identical with that of the mephitic, sulphuretted, oil-like fluid ejected by the skunks. Thus far anal glands are known to be present in the following families of Coleoptera: Cicindelidae, Carabidae, Dytiscidae, Gyrinidae, Staphylinidae, Silphidae, and Tenebrionidae. The blood itself serves as a

repellent fluid in the Meloidae, and in the Coccinellidae and Lampyridae, and it issues from a pore at the end of the femur as a yellowish fluid. The cantharidin in the blood of some species of Meloidae, commonly known as 'Spanish Fly,' forms an especially caustic protection against birds, predacious insects and reptiles." (Wade, J. S., Notes on defensive scent glands of certain Coleoptera, Psyche, vol. 28, nos. 5-6, p. 146, Oct.-Dec., 1921.)

Bird enemies.—It is worth pointing out that about 15 per cent of all the determinations of beetles were not carried to the family, and consequently that the percentages for the various families should be, on the average, about a seventh larger than shown in the tabulation

Identifications of Coleoptera

Family	Number of identifications [1]	Percentage of identifications among all Coleoptera	Percentage of species in this family among described nearctic species of Coleoptera [2]
Cicindelidae	649	.7666	.6146
Carabidae	15,887	18.6200	11.6730
Amphizoidae	...	...	.0107 (2)[3]
Omophronidae	16	.0187	.0808 (15)
Haliplidae	363	.4254	.2210
Dytiscidae	1,729	2.0264	1.7954
Gyrinidae	64	.0750	.0808
Hydrophilidae	2,418	2.8340	1.0244
Platypsyllidae	...	...	.0053 (1)
Brathinidae	...	...	.0161 (3)
Leptinidae	...	...	.0161 (3)
Silphidae	409	.4794	.7386
Clambidae	...	...	.0323 (6)
Scydmaenidae	...	...	.0381 (174)
Orthoperidae	4	.0047	.3073 (57)
Staphylinidae	1,605	1.8811	14.8163
Pselaphidae	3	.0035	1.9140
Clavigeridae	...	...	.0161 (3)
Ptiliidae	...	...	.4690 (87)
Sphaeritidae	...	...	.0053 (1)
Colydiidae	5	.0059	.4520
Murmidiidae	...	...	.0269 (5)
Monoedidae	...	...	.0053 (1)

[1] There is an omission of 737 records of Carabidae and 574 of Chrysomelidae, enough to make more than 1.5 per cent of the total of beetle records.

[2] Computed from Leng, C. W., Catalogue of the Coleoptera of America north of Mexico, 470 pp., 1920.

[3] The number of nearctic species in the family.

Identifications of Coleoptera—Continued

Family	Number of identifications	Percentage of identifications among all Coleoptera	Percentage of species in this family among described nearctic species of Coleoptera
Lathridiidae	16	.0187	.5607
Mycetaeidae Endomychidae	1	.0012	.2048
Phalacridae	27	.0316	.6308
Coccinellidae	1,455	1.7053	1.9517
Alleculidae	34	.0398	.6685
Tenebrionidae	2,197	2.5749	6.1411
Lagriidae	8	.0094	.0916
Monomidae	...	...	.0323 (6)
Melandryidae	39	.0457	.4367
Ptinidae Anobiidae	51	.0598	1.4556
Bostrichidae	24	.0281	.3288
Lyctidae	...	...	.0862 (16)
Sphindidae	...	...	.0323 (6)
Cisidae	4	.0047	.4582
Scarabaeidae	13,252	15.5317	5.3701
Lucanidae Passalidae	121	.1418	.1724
Cerambycidae	1,585	1.8577	6.0548
Chrysomelidae	5,666	6.6407	5.2515
Mylabridae	47	.0551	.5014
Scaphidiidae	8	.0094	...
Histeridae	1,663	1.2459	2.0704
Lycidae Lampyridae Phengodidae Telephoridae	879	1.0302	1.5095
Melyridae	38	.0445	1.7307
Cleridae Corynetidae	35	.0410	1.1806
Othniidae	...	...	.0269 (5)
Lymexylidae	...	...	.0107 (2)
Telegeusidae	...	...	.0053 (1)
Micromalthidae	...	...	.0053 (1)
Cupedidae	1	.0012	.0215
Cephaloidae	2	.0023	.0431
Oedemeridae	9	.0105	.2641
Mordellidae	34	.0398	.7656
Rhiphiphoridae	2	.0023	.1347
Meloidae	279	.3270	1.2239
Aegialitidae	10	.0117	.0161
Pythidae	6	.0070	.0916
Pyrochroidae	4	.0047	.0593

Identifications of Coleoptera—Continued

Family	Number of identifications	Percentage of identifications among all Coleoptera	Percentage of species in this family among described nearctic species of Coleoptera
Pedilidae, Anthicidae, Euglenidae	573	.6716	1.5311
Cerophytidae, Cebrionidae, Plastoceridae, Rhipiceridae	7	.0082	.1939
Elateridae	4,489	5.2612	3.1056
Melasidae	4	.0047	.3073
Throscidae	6	.0070	.1347
Buprestidae	662	.7759	2.0434
Psephenidae, Dryopidae, Helmidae	33	.0387	.3072
Heteroceridae	143	.1676	.0593
Georyssidae	...	...	.0107 (2)
Dascillidae, Helodidae	17	.0199	.3288
Chelonariidae	...	...	.0053 (1)
Dermestidae	190	.2227	.6955
Byrrhidae	312	.3657	.5229
Rhyssodidae	...	...	.0215 (4)
Ostomidae	28	.0328	.3450
Nitidulidae	327	.3832	.7117
Rhizophagidae	...	...	.0754 (14)
Monotomidae	3	.0035	.1941
Cucujidae	28	.0328	.4582
Erotylidae	14	.0164	.3828
Derodontidae	...	...	.0269 (5)
Cryptophagidae	18	.0211	.7278
Mycetophagidae	24	.0281	.1725
Brentidae	16	.0187	.0323
Platystomidae	29	.0340	.3342
Belidae	11	.0129	.0053
Curculionidae	11,740	13.7596	9.9153
Platypodidae	25	.0293	.0215
Scolytidae	494	.5790	2.0488
Water beetles (further unidentified)	369	.4325	...
Rhynchophora (further unidentified)	7,557	8.8570	...
Beetles (further unidentified)	7,192	8.4292	...
Beetle larvae (further unidentified)	862	1.0103	...

The tiger beetles "are avoided on account of their ferocity" (Bastin, Insects, their life-histories and habits, p. 151, 1913), and have been referred to as "dreaded insects" (Poulton, Colours of animals, p. 252, 1890), but what creatures capable of feeling dread so regard these beetles is unexplained; certainly the facts indicate they are not birds. The 649 records included in the present tabulation are distributed among 99 species of birds. Eight species have 10 or more records each, two others, the eastern meadowlark and eastern kingbird, over 20, the crow more than 60, and the crow blackbird 94. No fewer than 25 larvae of tiger beetles were found in a single stomach of an eastern bluebird, and 156 adults in that of a sparrow hawk and 164 in that of a long-billed curlew. If tiger beetles ever evade attacks by birds it is by celerity of motion rather than by any special defenses.

With respect to Carabidae or ground beetles, Forbes in his report on the food of thrushes may have given some comfort to protective adaptation theorists when he said: "We note, however, a remarkable deficiency of the highly colored genera—such as *Galerita, Brachynus, Lebia, Platynus, Chlaenius,* etc., which are either absent, or found but rarely in these birds' (thrushes, bluebird) food. Evidently these more showy beetles are protected by some more effective means than obscurity of color." (Forbes, S. A., Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 6, p. 57, May, 1883.)

However, this statement is but another instance of the danger of generalizing from insufficient data. In the study of the food of birds and other animals we are always adding to the list of species eaten and to the number of times they are taken; the movement is never in the contrary direction. We are constantly finding enemies of forms previously held to be more or less exempt, and usually to an extent which more than compensates for previous lack of knowledge on the subject.

In the present instance such progress in knowledge since Forbes' study is indicated by 535 records of the capture of *Chlaenius* by 41 species of birds, 254 for *Platynus* by 55 species, 44 records for *Galerita* by 13 species, 39 for *Lebia* by 21 species, and eight for *Brachynus* by seven species; figures more or less in harmony with the relative abundance in individuals of these groups. In this connection it may be well to note also F. H. Chittenden's remark that *Lebia grandis* "is protected by its warning color from rapacious birds." (Farmers' Bull. 1020, U. S. Dep. Agr., p. 16, 1919.) Six of the 39 *Lebia* records here cited are for *grandis*, and the writer submits that six records for this single species out of a total of 85,322 for all

beetles (18,548 nearctic species) fully satisfies expectations based on the relative availability of the species to birds.

Species of *Agonoderus*, much more common than *Lebia* but just as contrastingly colored, contribute 188 records to our tabulations and were eaten by no fewer than 57 species of birds. From 10 to as many as 50 specimens had in several instances been taken at a meal. There are 57 records for *Casnonia*, a small genus of "long-necked" distinctly "warningly-colored" beetles in stomachs of 14 species of birds.

Even black, alone, the predominant color among Carabidae has been held to have a warning value, but *Amara*, *Anisodactylus*, *Harpalus*, and *Pterostichus*, chiefly typically black species, are eaten by the hundreds. There are 445 records for the powerful *Pasimachus* (80 individuals in one crow stomach), and 497 for the species of *Calosoma* which are not only large, but some of which have contrasting blue margins, others fiery spots, and all powerful, ill-scented excretions. In fact, it is everywhere evident that the special defenses alleged for the Carabidae are more in the nature of pleasing fictions for theorists to speculate upon than practical reliances for the beetles concerned. Eloquent is the fact that between a sixth and a fifth of all determinations of beetles in the stomachs of nearctic birds are of Carabidae.

The Haliplidae, all of which have "warning colors," and the Dytiscidae and Gyrinidae, said to be protected by anal glands, all seem to be preyed upon in proportion to their abundance. The Silphidae quite generally have nauseous excretions and include numerous species with distinct warning colors, but it is the latter forms such as *Necrophorus* with 102 records and *Silpha* with 213 that most evidently are eaten in due proportion. The apparent falling of records of this family below the index of frequency must be attributed to the smaller and rarer species with more concealed habits being overlooked, rather than to the larger familiar ones enjoying immunity on account of alleged special defenses which they possess in the highest degree.

That the Staphylinidae is the family most numerous in species, and probably therefore of individuals, among all Coleoptera is a fact not realized by the average collector. It has been brought out only by the accumulated research of generations of coleopterists, and its lack of obviousness must be attributed to the secretive habits of so many of these small or even minute beetles. Most of them spend their lives chiefly under cover of various kinds, for example, in fungi, in leaf-mold, under bark, in old logs, and in ant nests, and it must be on this account that the records of birds capturing them are not very much more numerous, rather than that they are disliked. In fact the 1,605 determinations for them proves they are not disliked, and these

records are shared by more than 160 species of birds. Fifteen of these kinds of birds had more than 10 records each, nine others more than 20, six others from 30 to 60 records, one other, the chimney swift, 76, the crow 190, and another, the starling, more than 200. In several instances the number of specimens found in a stomach was as many as from 20 to 50 and larger numbers were 85 for the baldpate and 150 for the dowitcher. Such data certainly do not indicate distaste for Staphylinidae, hence the failure of the total number of captures to come up to theoretical expectations must be due to some other factor, presumably the small size and concealed habit of living characteristic of so large a proportion of the beetles of this family.

The same causes also serve to explain why a number of the minor families of beetles have not yet been identified in bird stomachs; the Platypsyllidae, and Leptinidae are parasitic upon mammals, the Scydmaenidae, and Clavigeridae mostly live in ant nests, the Ptiliidae are minute, while the others most of which have five or fewer species in our region owe their degree of immunity to their very rarity.

Passing now to one of the larger groups of beetles about whose protected status "there seems to be no doubt," namely the malacoderms, variously regarded as forming from one to four families, we find that they are devoured in no mincing way by nearctic birds. While various authors refer to these beetles (generally known as Lampyridae in the United States) in terms varying from distasteful to inedible or immune, our records show 879 determinations of them from bird stomachs. All of the groups were preyed upon, the Lycinae and Phengodinae least, however, because they are scantily represented in our fauna. The adult lampyrids identified were eaten by no fewer than 108 species of birds and the larvae by 25. Larvae in number up to 50 were found in a bluebird's stomach, and in three instances as many as 100 were taken from a single stomach of the robin. Our most common lampyrids are *Chauliognathus* and *Telephorus*. The former genus was identified 179 times in the stomachs of 34 species of birds. Three of these had from 30 to 38 records each and the number of individual beetles eaten ran as high as 30 in a single instance. *Telephorus* (*Cantharis*) were determined 274 times in the stomachs of 35 species of birds; the number of imagines in a stomach ran as high as 16 and of larvae, 100. If the Lampyridae fail in any degree to attain proportional representation among the food items taken by nearctic birds it is due to the nocturnal habits of a large number of the species. The diurnal species seem to be captured as frequently as would be expected.

The Melyridae (Malachiidae) are poorly represented compared to the Lampyridae, yet upon inspection of the records it does not seem that they are really avoided. Six genera and at least 10 species of these beetles were identified; 21 species of birds had eaten them, and for one of these birds, Say's phoebe, there were eight records of feeding on *Collops*. Identifications of the Cleridae again include numerous (21) species distributed among an equal number of species of birds. One of these birds, the red-eyed vireo, had eight of the records. In our experience Cleridae occur chiefly scattered and in small numbers, a type of distribution with which the records of birds preying upon them seem to harmonize.

Of the Histeridae, Donisthorpe says: "All the species of this family are protected by their oval shape and hardness. They also 'feign death.'" . . . . the "species which are spotted with red, are probably protected by their resemblance to Coccinellidae." (Trans. Ent. Soc. London, 1901, p. 354.) The prevailing color in this family, *i. e.* black, has also been said to have a warning significance. Our records show 1,063 identifications of Histeridae representing 116 species of birds; they are very freely eaten by some of these birds, the number of records per species exceeding 20 in the case of at least 12 kinds, and the number of specimens eaten at a meal running up to as high as 200 as a maximum.

The family of blister beetles (Mylabridae, Cantharidae, or Meloidae as it is variously known) is especially noted for the presence in the bodies of its members of a vesicant poison, cantharidin, of which as small a quantity as one grain has proved a fatal dose for a human being. Bastin says of them "the blood contains cantharidin, an extremely caustic substance, which is an almost perfect protection against birds, reptiles, and predacious insects." (Insects, their life-histories and habits, p. 167, 1913.) While these beetles are supposed to enjoy a very high degree of protection from natural enemies, 47 species of birds included in the tabulations here discussed had fed upon them. Seven of the species had 10 or more records apiece of preying upon blister beetles, the eastern kingbird having no fewer than 77. In some cases from 12 to 16 specimens of cantharids were found in single stomachs and a maximum of 31 in the case of a magpie; more than 30 species in all of these beetles were identified.

Pyrochroidae are said to be another specially defended group of the first order, but in view of the fact that there are only 11 nearctic species of the family and they usually rare, we believe that the four records of our birds capturing them are as many as could be expected. One of the birds eating Pyrochroidae, namely a hairy woodpecker,

must have had unusual luck in order to obtain the 12 specimens it contained.

Donisthorpe says " The Elaters ' feign death ' and their ability to ' skip ' . . . . is no doubt of great use to them. Mr. Holland points out that many of them possess a colour and shape suggesting the appearance of bits of dry brown stick." (Trans. Ent. Soc. London, 1901, p. 360.) Over four thousand (4,489) records of these beetles being eaten by nearctic birds show that the protective devices mentioned are of no particular account. There would appear to be no doubt whatever that birds feed upon Elateridae whenever available to them.

The larvae of Buprestidae live in wood, and the adults have hard chitin and metallic or other brilliant coloration, but since there are more than 650 records of their occurrence in the stomach contents of nearctic birds, it is certain that concealment of the larvae rather than color protection is their main defense. Heteroceridae or mud beetles certainly seem well concealed to the human eye but the records indicate they are taken fully in proportion to their abundance. Dermestidae, said to be protected because they are carrion-feeders, are taken freely considering their availability in nature. Byrrhidae are thought to be excellent examples of cryptically defended insects. " The legs and antennae are packed close to the body, fitting into cavities for their reception and the beetles then represent rabbits' dung, or little lumps of earth; they in no way suggest the appearance of living beetles." (Donisthorpe, Trans. Ent. Soc. London, 1901, p. 357.) However 312 records for them show American birds are not especially deceived by the alleged protective devices.

It is unnecessary to comment on every family, but coming to the Erotylidae we have a group which though small in numbers is said to be one of the most highly protected groups. However, in the United States, insects of this family in general do not have the bold habits supposed to be associated with warning colors; in fact most of them feed concealed in fleshy fungi. Correspondingly most of the determinations of beetles of this family are for the species which live exposed as *Languria,* for which there are 10 records, probably all that should be expected for a single small genus. Similarly the Endomychidae are protected by feeding inside of fungi or on fungi growing on the under side of logs rather than by their " warning colors." It should puzzle selectionists to explain why these and other brightly colored, supposedly distasteful insects have such retiring habits that their " warning coloration " is seldom displayed.

Contrasting these elusive beetles with another brightly colored but decidedly not secretive group they are supposed to mimic, the Coc-

cinellidae, it is easy to see what factor makes for greater depredations by birds; it is none other than the frequently mentioned "availability." Endomychids and Erotylids are red and black or yellow and black beetles, less abundant and much more retiring in habits; while coccinellids with the same colors are more common and live unconcealed. The former are relatively seldom captured, the latter are freely eaten. No better example of the influence of availability in guiding choice of food by birds could be desired. This despite universal acclaim of coccinellids as specially defended insects. "All the lady-birds are very gaily colored" says Donisthorpe. "They boldly walk about without any attempt at concealment, as do also their larvae. Both their larvae and pupae are very brightly spotted. The distastefulness of the perfect insects was proved[1] by Jenner Weir, and has since been confirmed by both Poulton and Wallace." (Trans. Ent. Soc. London, 1901, p. 354.)

Packard states that "The Coccinellidae are . . . . protected by a yellow mucilaginous disagreeable fluid oozing out of the sides of the thorax," (Journ. N. Y. Ent. Soc., vol. 3, p. 116, 1895), and Wallace says: "The Coccinellidae or lady-birds are another uneatable group." (Darwinism, p. 234, 1896.) Let us see. The total number of records of coccinellids in the food of nearctic birds is 1,455 and these are shared by 127 species. Twenty-seven kinds of birds had 10 or more records each, nine of which ran over 50, and three over 100. Not only is the effect of availability noted in birds eating more coccinellids than other similar but less abundant and conspicuous beetles, but its influence is evident in at least two other ways, namely that leaf-feeding birds, as warblers and vireos, get the most ladybird beetles, and that in California where coccinellids are notably more abundant than they are in the eastern States, a larger number of birds feed upon them and they get a great many more of the beetles. The largest numbers of coccinellids found in individual stomachs were 12 and 18 taken by English sparrows, 13 by the summer warbler, 14 by the warbling vireo, and 15 by the valley quail.

We now come to the consideration of three families (the Scarabaeidae and Cetoniidae being reckoned as one) which Poulton says are "at any rate partially distasteful." Regarding one of these families, the Lagriidae, which has only 17 species in the nearctic fauna, it

[1] The "proof" was experimental, of course; for the value of this proof see my 1912 paper. Also note that Meisner's results on the poisonous effect of Coccinellid juices (Ent. Bl. Nurnberg, vol. 5, no. 9, pp. 180-182, Sept. 20, 1909) are controverted by a repetition of his experiments by Heikertinger (Wien. Ent. Zeit., vol. 38, Heft 4-8, pp. 109-113, June 15, 1921).

may be said that almost any small number of captures by our birds would satisfy expectations. There are eight records distributed among six species of birds, about all that probabilities demand. As to the Tenebrionidae so many species of which have secretions nauseous to man, the nearly 2,200 records are eloquent of the fact that these beetles are not disliked by birds. If they do enjoy any degree of immunity from bird attacks, it is probably on account of their characteristic nocturnal or otherwise seclusive habits. The number of species of birds known to prey upon Tenebrionids is in excess of 175; nine birds had over 20 records each, five others more than 40, one additional over 50, and two others more than 100. The number of specimens taken at a meal ran up to 44 in two cases and to 46 in another and 53 in still another. The number of species of Tenebrionidae identified was over 100, including 12 of Eleodes, the largest and most potently odoriferous of the family.

Of these a recent article says: "It was interesting to note that the quantity of the secretion voided varies noticeably with the different species under observation, both under field and under laboratory conditions, and some of the species, notably *Eleodes tricostata* Say, undoubtedly have the habit of erecting the abdomen in a threatening manner when approached, though no secretion may be voided. Such species undoubtedly find protection through imitation of the threatening movements of their more formidable associates. Two of the characteristics of the Eleodes are their slowness of movement, and their habit of coming out of their hiding places about sunset for feeding purposes, and their presence is readily noticed on the bare sandy plains by birds, skunks, and other enemies, hence their protective secretion, or, in the absence of this, their threatening maneuvers are no doubt of highest value to them." (Wade, J. S., Notes on defensive scent glands of certain Coleoptera, Psyche, vol. 28, nos. 5-6, p. 148, Oct.-Dec., 1921.)

In this connection it may be said that our tabulations show 51 records of birds feeding on *Eleodes tricostata* and 109 for the other species. Other large Tenebrionids as *Asida* and *Nyctobates* are well represented in the table of determinations as are also the metallic forms such as *Helops*, *Meracantha*, and *Epitragus*. *Blapstinus* with 286 records for 11 species is the favorite genus, and the reason is what?—simply that it is the most widely distributed and the most numerous in individuals.

With respect to the other "partially distasteful" family of beetles, the Scarabacidae (sens. lat.), the more than 13,000 records in our tabulations speak for themselves. The selectionist protectionists have

simply made a very bad guess. Consider for instance the Cetoniini, the best "protected" tribe, some of which are said to mimic bees in flight. Our most numerously represented genus, *Euphoria*, has 445 records, of which 148 are for the most beelike species of all, *E. inda*. *Cotinis*, very poorly represented in our fauna, has 156 records, and *Cremastochilus*, noted for their association with ants, 77.

Species of *Onthophagus* "live in and about dung and are of a colour which conceals them well in those surroundings." (Donisthorpe, Trans. Ent. Soc. London, 1901, p. 358.) However, they were preyed upon 642 times by the birds included in the present tabulations. The species of *Aphodius* also are dung-feeders and said to be protected The number of determinations of this genus is approximately 3,565; in numerous cases 100 of these beetles were found in single stomachs and in one instance no fewer than 900. A warningly colored species, *A. fimetarius* (with the thorax black and elytra red), was identified in 913 stomachs. Consider the entirely different case of a beetle, the rose chafer (*Macrodactylus*), known to be actually poisonous (see Science, n. s., vol. 43, pp. 138-139, Jan. 28, 1916) besides having protective (cryptic) coloration and long spiny legs: although there are but two species in the country, we have 52 records in our tabulations representing 15 species of birds. The larger numbers of specimens taken were: nine by a crow, 12 by a road-runner, and from 15 to 40 in five instances by the eastern kingbird. These records show that the most potent protective adaptations possible do not necessarily protect. The highly significant fact about the case is that predators do not seem to recognize the dangerous qualities of the rose chafer; every generation of young chicks and pheasants will pay a heavy death toll if permitted to stuff themselves with these beetles. Even trout kill themselves in the same way. But what advantage is all this to the beetle? Those that cause the death of some predators, themselves lose their lives, that is, all of those actually proved "fit" in this respect are eliminated; the only effective poisonous action is upon young (among birds)—adults can and do eat them freely. No considerable body of predators has ever been killed, and "warning color" has not been acquired (the rose chafer is a uniform and inconspicuous brownish-yellow). Theories as to protective adaptations seem to suffer from every angle of this case. (For fuller discussion of the subject see Lamson, Geo. H., Journ. Econ. Ent., vol. 8, no. 6, pp. 547-548, Dec., 1915; Bates, J. M., Science, n. s., vol. 43, pp. 209-210, Feb. 11, 1916; and McAtee, W. L., The Auk, vol. 33, no. 2, pp. 205-206, Apr., 1916.)

Some curiosity may be felt as to the relations of birds to the large Scarabaeidae and Lucanidae with thoracic horns and especially strong or greatly enlarged mandibles. In nearctic America we have few species in any of these groups; another limiting factor important in relation to bird predators is the large size of these beetles. Nevertheless all of the genera are represented in the food of birds, *Passalus* by 32 records, *Platycercus* by 19, *Lucanus* by 25, *Ceruchus* by three, *Dorcus* by six, *Sinodendron* by seven, and lucanids further unidentified by 28 determinations; our largest scarabaeid, *Dynastes* is represented by five identifications, *Strategus* by 27, *Xyloryctes* by seven, *Copris* by 62, and *Phanaeus* by 252. The latter genus, besides being "horned," has brilliant metallic colors.

The long-horned beetles or Cerambycidae include many species with showy colors, but selectionists as a rule have not attributed distasteful qualities to the group; rather they have considered these beetles mimics of various more strongly "protected" insects such as wasps and other Hymenoptera and weevils. Numerous longicorns have cryptic coloration also, but their chief defense must be residence of the long larval stages in wood where they can be reached only by a small proportion of insect predators. The imago state, only in which the colors theorized about are displayed, is of relatively short duration. Bearing these facts in mind we believe the records show that longicorns are fed upon to such an extent as to indicate that in proportion to availability they contribute their due share to the subsistence of birds.

The total number of determinations in the present tabulations is 1,585, shared by 162 species of birds. Twenty-one kinds of birds have from 10 to 19 records each; six additional species from 20 to 29; six others from 30 to 39; one other 42; still another 53; and two as many as 169 and 173 respectively. The woodpeckers, on account of their peculiar qualifications for obtaining the larvae, naturally are the chief enemies of Cerambycidae. Several of the species prey upon these beetles to the extent of from 10 to 50 per cent of their total food. The number of adult beetles taken at a meal by these or other birds exceeded 30 in a number of cases and in four ran as high as 83, 100, 102, and 168. The last named figure is for one of our most wasplike species, *Xylotrechus colonus*, in the stomach of a raven. There are 10 identifications of *Xylotrechus;* of the other wasp-colored longhorns, we have the following numbers of determinations: *Cyllene*, 10 (28 specimens of *C. robiniae* in the stomach of a magpie); *Calloides nobilis* 1, *Neoclytus* 11, *Clytanthus* 12, *Clytes* 5, *Strangalia* 6, *Typocerus* 16, and *Leptura* 39. It is noticeable that the numbers appended

correspond very closely to the relative abundance in individuals of these genera. Of the ant-suggesting genera, we have for *Euderces* five records and for *Cyrtophorus* one; and for the ichneumonid-mimic *Neolorchus* three identifications.

The figures for the distinctly warningly colored genera are *Acmaeops* seven, *Desmocerus* two, *Gaurotes* two, *Tetraopes* nine, and *Oberea* five. Such a catalogue shows that all the forms, whatever their alleged "protection" are eaten more or less, and there is no other explanation of the comparative extents to which they are taken so reasonable and satisfying as that it probably depends almost entirely on their relative abundance and availability to birds.

The Chrysomelidae or leaf beetles are classed by Professor Poulton as undoubtedly specially protected, and Donisthorpe writing of them under another name says: "The Phytophaga are considered to be all more or less distasteful, and no doubt justly so. Many species have been proved to be so, and the group is mimicked by various orders of beetles throughout the world." (Trans. Ent. Soc. London, 1901, p. 367.) Selectionists should have been somewhat restrained in their theorizing by the very name Phytophaga, for the leaf beetles and their allies being groups that subsist directly upon vegetation, must according to inevitable law in the organic world form the base of a column of predacious life more or less exclusively dependent upon them. Like the grazing mammals, all plant-feeding insects, no doubt, have their lions, wolves, and eagles, their hyaenas, jackals, and vultures.

No reason appears from the records of bird food here discussed to warrant doubt that the leaf beetles do in fact contribute their full quota toward the subsistence of predatory animals. The total number of identifications of Chrysomelidae is 5,666, and these are shared by well over 200 species of birds, so it is certain that practically all of our birds feed more or less upon these beetles. More than 230 species of Chrysomelidae are represented in the determinations, this in turn indicating that all tribes of the family are preyed upon. The Cassidini, on account of their bright colors and specialized larvae, receive frequent mention as a specially protected group but our scant representation of this tribe seems to bear its share of bird predation; *Cassida* 3 records, *Physonota* 2, *Coptocycla* 48, and *Chelymorpha* 48. Again correspondence of the number of identifications with observed frequency of the insects is quite evident.

Resemblance to caterpillar droppings always is spoken of by selectionists as a prime defense, and one tribe of our leaf beetles, the Chlamydini, exhibits this to a high degree. When feigning death, as

they do when disturbed, they "resemble the excrement of certain caterpillars so closely as to render their detection difficult . . . . and it is said that birds will not pick them up." (Blatchley, Coleoptera of Indiana, p. 1,114, 1910.) Two genera represent this tribe in our fauna and of these, *Chlamys* has been found 56 times in bird stomachs and *Exema* 17 times; 10 of the latter beetles were contained in a single stomach of a Bewick's wren. The number of determinations cited, in view of the few species we have of this tribe, fully satisfies the probabilities.

The genus *Diabrotica*, chiefly yellow and black species, has received special attention from the standpoint of protective adaptations. "I believe," says C. J. Gahan, "that the species of *Diabrotica* are protected, and that the species of *Lema* derive advantage by mimicking them." (Trans. Ent. Soc. London, 1891, p. 369.) The tabulations of bird food here discussed show 41 records of *Diabrotica vittata* distributed among 17 species of birds; 107 of *D. 12-punctata* for 42 species of birds (18 specimens being found in a stomach of a cliff swallow); and 194 records of *D. soror* for 22 kinds of birds (a black-headed grosbeak had eaten 21 of these beetles). There are also 34 other records for scattering and unidentified species of the genus. Thus there is no evidence of special protection for *Diabrotica;* as for *Lema* the species are much less numerous in individuals, and that is the real reason they are captured less frequently by birds; we have 22 identifications shared by 14 species of birds.

One other Chrysomelid, the Colorado potato beetle (*Leptinotarsa 10-lineata*), has had its protective adaptations pointed out on numerous occasions, and like the rose chafer, among the Scarabaeidae, seems to be actually poisonous. (See Riley, Seventh Missouri Rep., 1875, pp. 6-7.) However, our records show that 23 species of birds devour the insect and 11 others are added by the literature of the subject. One hundred and eighteen identifications of this pest are included in our tabulations; the larger number of specimens found in single stomachs are 8 in that of a starling, 10 in a sharp-tailed grouse, 12 in a black-headed grosbeak, and 14 in a rose-breasted grosbeak. Birds such as the bob-white, crow, and rose-breasted grosbeak are recorded as having cleared fields of these pests.

Before leaving the Phytophaga or Chrysomelidae it may be well to cite certain records of large numbers of individuals being taken at a meal by birds, since they show not only that there is no restriction of bird attack to certain tribes of the family but also that there is no restriction of the more important avian predators to certain groups of birds. Some of the larger records are: 36 specimens of *Micro-*

rhopala vittata taken by a starling; 47 *Donacia* by a red-winged blackbird; 50 of *Systena* sp. by a Baird's sparrow; 50 of *Disonycha caroliniana* by a horned lark; 58 of *Myochrous denticollis* by a house wren; 212 *Donacia subtilis* by a Franklin's gull; 250 *Colaspis brunnea* by a nighthawk; and about 300 *Epitrix cucumeris* by each of five individual tree swallows.

Bruchidae spend so much of their lives within seeds that they are little exposed to attack by birds; an advantage which probably is compensated for by their being devoured with the seeds by some birds and other seed-eating animals. However, this is a subject that has scarcely been investigated. Our 47 records represent nine or more species of bruchids and were distributed among 29 species of birds. Expectations based on availability of free bruchids probably are satisfied.

The great series or suborder of beetles known as the weevils or Rhynchophora, for the most part, are said to be cryptically colored, resembling seeds, buds, bark, bits of earth, bird droppings, etc. Wallace adds: "One of the characters by which some beetles are protected is excessive hardness of the elytra and integuments. Several genera of weevils (Curculionidae) are thus saved from attack and these are often mimicked by species of softer and more eatable groups." (Darwinism, p. 260, 1896.) However, it should be pointed out at once that those who predicate hardness as a defense against predators do so without due reflection upon the digestive powers of animals.

Recall the fragmentation and gulping down of bones by dogs; the swallowing of snails, shells and all, by squirrels; while reptiles, amphibians, birds of prey, and predatory mammals either swallow their vertebrate prey whole or in large pieces, the bones included; waterfowl and shorebirds habitually take shellfish entire, including such hard-shelled forms as clams and oysters; gallinaceous birds are provided with gizzards which grind up the hardest seeds; and finches and numerous other birds are just as effectively equipped if on a smaller scale. Not only do birds with gizzards grind up their food materials, but the grit and pebbles they swallow are in most cases gradually ground down and pass out through the intestines in the form of fine sand. Most predators, in fact, have either a powerful mechanical or a resistless chemical digestion that as a rule is fully competent to dispose of anything entrusted to it. With such digestive powers at the service of predators, it is extremely unlikely that hardness in the degree possessed by weevils is any bar to their being eaten; moreover being jointed, weevils are thoroughly susceptible to chemical digestion.

In illustration of the factor of hardness as related to bird food the three genera *Lixus, Thecesternus,* and *Sphenophorus,* representing as many families of weevils, may be discussed. *Lixus* is so hard that the entomologist usually finds drilling a necessary preliminary to pinning; moreover the species are full of vitality, sometimes living through 24 to 36 hours in the cyanide bottle. Records of this genus in our tabulations total 102, distributed among 27 species of birds. No fewer than 18 specimens were found in a single stomach of a nighthawk. *Thecesternus,* a weevil with unusually thick and hard integument, was identified 151 times in the stomachs of 22 species of birds. Twelve specimens were taken by a meadowlark at a meal and 15 by a robin. The billbugs of the genus *Sphenophorus* not only are hard, but like *Lixus* have much ability to resist the fumes of cyanide and prolonged submersion in water. However 1,397 determinations were made representing 34 species of these weevils. They were found in the stomachs of no fewer than 110 species of birds. Some of the larger numbers taken from single stomachs were: 10 in the cases of the upland plover, clapper rail, and yellow-headed blackbird; 11 in a robin; 12 in an avocet; 17 in a crow blackbird; 20 in a killdeer; 33 in a crow; and 34 in a magpie.

Hardness thus appears to be of no consequence as a defense. Brief attention may be paid to a few other of the so-called protective devices of weevils. One of the obscurely colored genera, with the habit of dropping to the ground and feigning death, is *Rhinoncus;* such weevils are said to resemble seeds, but what good this would do, since most birds eat seeds, theorists have left unexplained. *Rhinoncus* has been identified 73 times from the stomachs of 30 species of birds, of one of which, the olive-backed thrush, an individual had eaten 20 of these weevils. *Rhodobaenus,* our only conspicuous red and black weevil, was identified 14 times in the stomachs of 10 species of birds, and *Tyloderma,* black weevils with whitish or yellowish markings, 133 times in 48 species of birds. Fifteen specimens of *Tyloderma* were taken from the stomach of a meadowlark.

To mention the relations of birds to a few representative genera of weevils, we may record that the rare *Otidocephalus* were identified six times in the stomachs of an equal number of species of birds; that the minute *Apion* were taken 91 times by 36 species; the nut weevils (*Balaninus*) 380 times by 85; the cotton-boll weevil (*Anthonomus grandis*) 348 times by 43 species of birds (23 other species are recorded as enemies in the literature); the alfalfa weevil (*Hypera murinus*) 2,222 times by 50; the clover root weevils (*Sitona*) 1,611

times by 94; the engraver beetles (*Ips* [*Tomicus*]) 120 times by 24; and the Anthribidae 29 times by 21 species.

A few of the larger numbers of weevils found in single stomachs also may be cited; thus 109 *Dorytomus mucidus* were found in one stomach of a downy woodpecker; 153 *Calandra oryzae* in a barn swallow; 167 *Barypithes pellucidalis* in a starling; 282 *Hyperodes* sp. in an eared grebe; and 281 larval and adult alfalfa weevils in a Brewer's blackbird, 300 in a killdeer, and 317 in a valley quail.

The nearly 20,000 identifications of weevils in birds' stomachs attest to the frequency of their capture, and records such as those just cited to the relish with which they are eaten.

Though to all weevils are attributed various protective adaptations, weevils of all sorts are preyed upon; the secret of the whole relationship between prey and predator in this as in other cases is distribution of the attack. All available food supplies are sought by predators and the amount of attention they receive is in direct proportion to their availability.

Total number of identifications, of Coleoptera 85,322; percentage of identifications among those of all insects, 44.6899; percentage of species in this order among those of all insect species known, 46.2032.

Other enemies.—It is difficult to summarize what is known regarding the predatory foes of so extensive an order as the Coleoptera. Fresh-water fishes prey systematically upon both larvae and adults of the aquatic beetles but secure other forms only incidentally. However it appears that falling into the water or otherwise becoming available as prey for fishes is a more or less frequent happening to terrestrial beetles, since most of the families are represented in the food of these animals. (See especially Forbes, papers, bibliography p. 188.)

Kirkland reports Coleoptera as making up the following percentages of the food of 149 common toads: ground beetles and their allies, 8 per cent; May beetles and allies, 6 per cent; wireworms and allies, 5 per cent; weevils, 5 per cent; potato beetles and allies, 1 per cent; carrion beetles, 1 per cent; and miscellaneous beetles, 1 per cent. Drake found Coleoptera to constitute 33 per cent of the whole number of animals consumed by 209 leopard frogs and 54 per cent of the insects. The number of specimens of various families identified was: Carabidae 176, Cicindelidae 44, Hydrophilidae 1, Staphylinidae 12, Coccinellidae 13, Erotylidae 1, Elateridae 1, Spondylidae 2, Cerambycidae 4, Chrysomelidae 2, Tenebrionidae 1, and Rhynchophora 146. It is worth noting that this author says of weevils: "The habit of these insects of dropping to the ground when disturbed gives the frog a chance to capture

them." This is just the habit the selectionists have declared protective. Klugh reports finding 35 Colorado potato beetles and five other Coleoptera in 25 stomachs of the leopard frog. Surface's report shows that other frogs and toads feed extensively upon beetles, the larger families contributing most heavily; the salamanders also eat a great many beetles, especially aquatic forms. Lizards, snakes, and turtles also feed upon beetles, some of the smaller terrestrial snakes taking a great many of them. Pack reports lizards feeding on beetles of such "protected" groups as Coccinellidae, Erotylidae, Meloidae, and Chrysomelidae.

Among mammals, moles and shrews prey freely upon beetles, taking Scarabaeidae and their larvae more and wireworms and ground beetles less often. Spermophiles, prairiedogs, chipmunks, squirrels, grasshopper mice, and other rodents as well as raccoons, foxes, and coyotes prey upon beetles occasionally, and such animals as bats, skunks, and armadillos depend upon them to a much larger extent. There is no reason to believe that the "protected" groups of beetles fare any better with mammalian than with avian predators. However citation of a few instances of the capture of such beetles may be advisable. A series of three armadillo (*Tatu novemcinctum*) stomachs from Texas contained Carabidae and Scarabaeidae in profusion, also weevils, Histeridae, Lampyridae, Staphylinidae and Tenebrionidae (including *Eleodes*). The stomach of a skunk (*Mephitis occidentalis*) collected at Nelson, Calif., held 60 per cent of pupae of the Colorado potato beetle; two shrews (*Sorex vagrans amoenus*) from Crater Lake, Ore., had fed on Silphidae, one to the extent of 50 per cent, the other to 100 per cent of the total food. A prairiedog (*Cynomys gunnisoni*) from Magdalena, N. Mex., had nothing but remains of *Calosoma triste* in its stomach, and a badger (*Taxidea taxus*) from Ash Meadows, Nev., had eaten no fewer than 150 *Calosoma prominens*.

Passing to the enemies of beetles in the insect kingdom, it is well known that the various predatory tribes make no exception of beetles even though their generally hard integuments would seem to be a bar. Mantids, chrysopids, robber flies, predacious bugs and beetles, wasps, ants, dragonflies, and spiders all feed upon beetles, and every tabulation of the species eaten by them shows "protected" forms liberally represented. Beetles are subject to numerous parasites which attack them in all stages from egg to imago, and like most insects, they at times are decimated by fungal or bacterial intruders.

While it has been impossible in the limits of this paper to discuss fully the enemies of beetles other than birds, a few cases may be cited

in more detail as showing how the activities of such foes supplement the predatory activities of birds. Take for example the wood-boring beetles, which although they are eaten by birds to an extent that indicates that no special protective adaptation operates in their favor, yet are shielded from most birds during the greater part of their lives by living under bark or even within solid wood. However this habit does not put them out of the reach of predatory and parasitic insects. Thus Kleine records 159 hymenopterous parasites of Cerambycidae, and 136 beetle predators and 157 hymenopterous parasites of Scolytidae in Europe. (Ent. Bl. Nurnberg, vols. 4-5, 1908-1909.) The cotton-boll weevil (*Anthonomus grandis*) again passes the larval and pupal stages apparently well hidden from most enemies, yet some of the 66 kinds of birds known to prey upon it remove the immature stages from the cotton bolls, and in addition the weevil has 54 insect enemies, about half of which attack the concealed stages. (Bull. 100, U. S. Bur. Ent. 1912.)

So it is with the mechanically protected species; all have in the chains of their life histories weak links, of which hungry predators and assiduous parasites are not slow to take advantage. For contrast, consider the case of the Colorado potato beetle, an insect exposed almost throughout its life history, and with all of the attributes—color, reflex bleeding, nastiness, even poisonous qualities—of a most highly "protected" insect. Besides the 27 species of wild birds known to feed upon this insect, ducks, chickens, guinea fowls, skunks, snakes, frogs, toads, at least eight species of Pentatomidae, two of Reduviidae among bugs, and eight of Coccinellidae and seven of Carabidae among beetles, besides robber flies, wasps, spiders, phalangids, and mites prey upon the various stages. Despite all of its protective adaptations, the Colorado potato beetle undoubtedly has its full quota of foes; its rapid increase and spread over the United States was due to enormous increase by cultivation of a favored food plant and not to lack of enemies. Dr. F. H. Chittenden remarks: "Few, if any, noxious insects have so many recorded natural enemies as the Colorado potato beetle." (Bull. 82, pt. 7, U. S. Bur. Ent., p. 85, Feb., 1911.) In other words, the potato beetle, being an important economic insect, has been much studied, and among other things we have learned that it has numerous enemies. If less were known about the species it would be hailed as a marvelous instance of protective adaptation; facts are a terrible handicap to theorizing.

Discussion.—In general we have seen that whatever the beetle, something in the way of protective adaptation has been claimed for it, yet practically all are eaten. On the other hand we have also seen that

the large families of Coleoptera, those abundant in individuals, are most freely eaten by birds, while the small families with few species escape with small losses. It is the old story over again of food supplies (beetles in the present consideration) being drawn upon in proportion to their abundance and availability.

MECAPTERA (SCORPIONFLIES)

Protective adaptations.—The scorpionflies are predacious; those of the genus *Panorpa* commonly have yellow bodies and black markings in the wings; and the males have enlarged genitalia carried aloft somewhat like the stings of scorpions. The species of *Bittacus* resemble crane flies.

Bird enemies.—We have only five records of scorpionflies being eaten by nearctic birds, these being distributed among four species.

Number of identifications, 5; percentage of identifications among those of all insects, .0026; percentage of species in this group among the whole number of insect species, .0260.

Other enemies.—There seem to be no records of such.

Discussion.—Poverty of data is the chief characteristic of the record for scorpionflies. These insects are not an obtrusive part of the insect fauna and have been little studied. The question of the efficiency of their protective adaptations in relation to predators can hardly be intelligently discussed at present.

DIPTERA (FLIES)

Protective adaptations.—Not much has been written about the protective adaptations of diptera, the suggestion most often made being that a considerable number of them "closely resemble wasps, and bees, and no doubt derive much benefit from the wholesome dread which those insects excite." (Wallace, Natural selection, p. 69, 1891.) The families that have the most numerous species supposed to resemble Hymenoptera are the Stratiomyidae, Bombyliidae, Asilidae, Conopidae, and Syrphidae. Many flies have metallic colors, which are alleged to be warning; such insects are common among the Stratiomyidae, Dolichopodidae, Tachinidae, and Muscidae. A large number of Diptera pass the greater part of their lives in the larval stage and many of these larvae are more or less protected from birds by their habitat, as the Cecidomyidae in galls, the Mycetophilidae and others in fungi, the Culicidae, Chironomidae, many Tipulidae, the Simuliidae, Stratiomyidae, Tabanidae, and Ephydridae in mud or water; and various others in excrement and other decaying organic matter. Of course this sort of protection is of no avail in the case respectively of

birds which eat galls or fungi or which obtain their food chiefly in or about water, or which feed directly upon or by tearing up carrion and the like.

Bird enemies.—Until comparatively recently it was very difficult to get identifications of flies found in bird stomachs, and even more so of their larvae, hence nearly half of the identifications of Diptera were not carried further than to the order.

The large proportion of the unidentified to the total number of records of Diptera has one advantage, namely that it is distributed probably among nearly as great a number of species of birds as are the records for all flies. Since that number exceeds 250, we may be sure that there is no group of birds that habitually avoids Diptera. Among these records are numerous instances of from 50 to 500 specimens of flies or their larvae being taken at a single meal, good evidence that the flies concerned were not at all distasteful. These data are sufficient commentary also on the state of determinations of Diptera, scores of specimens being present and not being named even to the family. The material will be re-examined in the future to obtain more satisfactory results, but there has been no time for that in connection with the present paper, which is wholly a by-product.

A satisfactory discussion of the relations of birds to Diptera is hardly possible therefore, and the best that can be done is to present the fragmentary data available and to make allowances for deficiencies.

Identifications of Diptera

Family	Number of identifications	Percentage of identifications among those of all Diptera	Percentage of species in this family among the whole number of nearctic Diptera [1]
Tipulidae	1,565	14.4426	5.7309
Dixidae	3	.0277	.0922
Psychodidae	5	.0461	.3920
Chironomidae	1,003	9.2562	3.0903
Culicidae	112	1.0336	1.9257
Mycetophilidae	53	.4891	2.9058
Cecidomyidae	15	.1384	1.6835
Bibionidae	140	1.2920	.8648
Simuliidae	8	.0738	.3173
Blepharoceridae	1	.0092	.1384
Rhyphidae	1	.0092	.0807
Orphnephilidae	...	...	.0115
Stratiomyidae	732	6.7553	3.4362
Tabanidae	336	3.1008	3.5285
Acanthomeridae	...	...	.1153

[1] Computed from Aldrich, J. M., A catalogue of North American Diptera, etc., Smithsonian Misc. Coll., vol. 46, pp. 1-680, 1905.

Identifications of Diptera—Continued

Family	Number of identifications	Percentage of identifications among those of all Diptera	Percentage of species in this family among the whole number of nearctic Diptera
Leptidae	42	.38,6	1.4644
Nemestrinidae	...	...	.0692
Cyrtidae	1	.0092	.4843
Bombyliidae	8	.0738	5.2581
Therevidae	5	.0461	.8187
Scenopinidae	1	.0092	.1268
Mydaidae	...	...	.5074
Apioceridae	...	...	.0807
Asilidae	170	1.5688	6.3536
Dolichopodidae	86	.7936	6.2959
Empididae	48	.4430	5.4196
Lonchopteridae	...	...	.0346
Phoridae	9	.0830	.7380
Platypezidae	...	...	.2998
Pipunculidae	...	...	.3229
Syrphidae	259	2.3902	9.3401
Conopidae	...	...	1.0378
Oestridae	4	.0369	.3459
Tachinidae	54	.4983	12.6841
Dexiidae	...	...	1.9833
Sarcophagidae	102	.9413	1.4183
Muscidae (sens. lat.)	512	4.7250	...
Anthomyiidae	109	1.0059	3.4478
Scatophagidae	79	.7290	.9917
Heteroneuridae	7	.0646	.1614
Helomyzidae	11	.1015	.4728
Borboridae	29	.2676	.2767
Phycodromidae	20	.1846	.0231
Sciomyzidae	13	.1200	.7380
Sapromyzidae	24	.2215	1.2338
Ortalidae	18	.1661	1.7181
Rhopalomeridae	...	...	.0346
Trypetidae	10	.0923	2.3984
Micropezidae	...	...	.7380
Sepsidae	8	.0738	.3344
Psilidae	...	...	.2883
Diopsidae	...	...	1.0115
Ephydridae	305	2.8147	1.6720
Oscinidae	20	.1846	1.5451
Drosophilidae	2	.0184	.8763
Geomyzidae	1	.0092	.1730
Agromyzidae	2	.0184	1.0954
Hippoboscidae	1	.0092	.5304
Nycteribiidae	...	...	.0576
Unidentified	4,904	45.2566	

From the foregoing table it is evident that crane flies (*Tipulidae*), midges (*Chironomidae*) and mosquitos (*Culicidae*) are adequately represented, and it is fair to say that an important reason for this showing is that the groups of birds eating most of these flies and their larvae have been examined rather recently and that in consequence closer identification of their food items has been made. This would indicate that records for the other families will be similarly increased by future studies. It is worth noting that most of the larvae of Chironomidae which are so commonly eaten by birds are red (a warning color) so much so as to be popularly called "bloodworms." There are numerous instances of hundreds of these larvae being taken at a single meal.

The more than 10,000 records of Diptera mark these insects as a valuable bird food; as in other cases certain birds prey to a greater extent upon the group than others; of these may be cited seven species of swallows which make 13 per cent to 40 per cent of their total food of flies and an equal number of flycatchers consuming them to the extent of from 11 per cent to 44 per cent of their entire subsistence.

Total number of identifications, 10,836; percentage of identifications among those of all insects, 5.6757; percentage of species in this order among the whole number of insect species known, 11.4432.

Other enemies.—Fishes are among the most important enemies of flies having aquatic immature stages. Pearse, writing of the food of 33 species of fishes in Wisconsin lakes, reports 20 per cent of their food to consist of flies and their larvae, chiefly the latter. Marine Chironomidae are eaten by shrimps and sea-anemones. A variety of fishes, the top minnows and killifish in particular, are such efficient enemies of mosquito larvae that they have been widely used in mosquito-control campaigns. Diptera are eaten quite freely by frogs and toads and to a lesser extent by lizards, snakes, and turtles. Among mammals, shrews, moles, and bats feed regularly and extensively upon Diptera; other mammals that get at least some Diptera are mice, squirrels, foxes, and armadillos.

Among their own kind, *i. e.*, insects, about all the predacious kinds feed freely on flies. The latter are soft-bodied insects easily pierced by the sucking predators or chewed up by the biting kinds. Tiger beetles, assassin bugs, mantids, ants, panorpids, dragonflies, and robber flies and other predacious members of their own order habitually feed upon flies. A number of families of wasps, such as the Nyssonidae, Bembecidae, Crabronidae, and Vespidae, prey freely upon Diptera, and spiders gain from their ranks a considerable share of their sub-

sistence. Flies appear to be subject to parasitism only to a comparatively slight extent but some of them are decimated by fungal diseases.

Discussion.—While flies in the adult stage appear to have a degree of freedom from predators, it is evident that the immature stages of many groups of them pay a heavy toll; the chief food of predacious fly and beetle larvae that live under bark, in decaying fungi or carrion are the fly larvae they find there; the chief food especially of the young of a great many fresh-water fishes again are fly larvae and pupae; and a very important element of the food of the mold- and earth-traversing shrews and moles are the larvae of flies. Fly larvae perish in large numbers also because of the drying up or exhaustion of their breeding nidus. Possibly some relative good fortune for the adults may be only compensatory, but so little is known about the subject that discussion is not on a very firm basis. Regarding the fate of adults it is worth while recalling the all but universal destruction at times wrought among the ranks of its hosts by the fungus *Empusa muscae.*

Evidence showing the importance of availability as regulating the consumption of dipterous food is presented in testimony of an Alaskan correspondent about birds feeding on mosquitos. These insects, so much more prominent an element of the insect fauna of that territory than they are in the United States, apparently are fed upon much more freely by birds. This correspondent, A. H. Twitchell, a reindeer breeder, reports all small birds frequenting the vicinity of his camp, as myrtle, blackpoll, and Wilson's warblers, Gambel's sparrow, and Alice's thrushes preying regularly on mosquitos and feeding them extensively to their young.

HYMENOPTERA (ANTS, BEES, WASPS)

Protective adaptations.—In selectionist writings, Hymenoptera usually are classed as the very acme of protected insects, and protective qualifications are broadly assigned to the whole group. Poulton says: "Ants and wasps are known to be aggressive dominant insects avoided by the majority of insect-eating animals." (Essays on evolution, p. 281, 1908.) Drummond, in similar vein, declares that "well-armed or stinging insects are always conspicuously ornamented with warning colours. The expense of eating a wasp, for instance, is too great to lead to a second investment in the same insect, and wasps therefore have been rendered as showy as possible so that they may be at once seen and as carefully avoided. The same law applies to bees, dragonflies, and other gaudy forms; and it may be taken as a rule that all gaily-coloured insects belong to one or other of these two

classes; that is, that they are either bad eating or bad stingers." (Tropical Africa, p. 163.)

Mimicry of a group is supposed to be a tribute to its specially defended character and it is said that: "The hymenoptera including the formidable hornets, wasps, bees and ants are more frequently mimicked than any other order." (Poulton, The colours of animals, p. 245, 1890.) "Stinging hymenoptera . . . . are sedulously avoided by insectivorous creatures in general." (Bastin, Insects, their life-histories and habits, p. 247, 1913.) Numerous Hymenoptera which do not possess stings are said to mimic those that do have them and species of one non-stinging group, the sawflies, are alleged to be protected in the larval stage by distasteful or disagreeable internal or external secretions.

Bird enemies.—For many years difficulty was experienced in obtaining identifications of hymenoptera and the following table plainly shows the effect of this situation, more than a third of the determinations being to the order only.

Identifications of Hymenoptera

Family	Number of identifications	Percentage of identifications among those of all Hymenoptera	Percentage of species of this family among the whole number of species of these groups in New York State [1]
Xyelidae	2	.0074	.4640
Pamphiliidae	5	.0185	1.2529
Tenthredinidae	263	.9732	17.5407
Xiphydriidae	5	.0185	.3248
Siricidae	16	.0592	.3719
Cephidae	2	.0074	.2320
Oryssidae	1	.0037	.1392
Tenthredinoidea (further unidentified)	85	.3145	...
Vipionidae	72	.2664	.9745
Alysiidae	13	.0481	.2320
Capitoniidae	1	.0037	...
Braconidae	28	.1036	9.0488
Evaniidae	5	.0185	.3719
Trigonalidae	1	.0037	.6496
Ichneumonidae	1,113	4.1184	25.6614
Ichneumonoidea (further unidentified)	13	.0481	...

[1] Computed from Bradley, J. Chester, Hymenoptera, in A list of the insects of New York, etc., Mem. 101, Cornell Univ. Agric. Exp. Sta., pp. 870-1,033, 1926, the most comprehensive checklist of nearctic forms available.

Identifications of Hymenoptera—Continued

Family	Number of identifications	Percentage of identifications among those of all Hymenoptera	Percentage of species of this family among the whole number of species of these groups in New York State
Figitidae	14	.0518	.0464
Cynipidae	38	.1406	6.7286
Pteromalidae	22	.0814	.9280
Eupelmidae	3	.0111	.1392
Callimomidae	12	.0444	.6032
Eurytomidae	5	.0185	1.5313
Perilampidae	3	.0111	.0464
Chalcididae	73	.2701	3.1091
Leucospidae	1	.0037	.0464
Chalcidoidea (further unidentified)	14	.0518	...
Platygastridae	7	.0259	.7889
Scelionidae	4	.0148	1.1137
Ceraphronidae	2	.0074	...
Diapriidae	12	.0444	.4640
Belytidae	7	.0259	.5568
Serphidae	8	.0296	.4176
Pelecinidae	9	.0333	.0464
Serphoidea (further unidentified)	18	.0666	...
Formicidae	2,092	7.7410	1.1137
Myrmicidae	1,200	4.4404	1.2529
Formicoidea (further unidentified)	9,451	34.9715	...
Chrysididae	61	.2257	1.0673
Bethylidae	9	.0333	.1392
Dryinidae	4	.0148	.3248
Scoliidae	285	1.0546	.9281
Myrmosidae	3	.0111	.0928
Mutillidae	23	.0851	.9745
Psammocharidae	36	.1332	3.6195
Eumenidae	35	.1295	1.8562
Vespidae	144	.5328	.5104
Vespoidea (further unidentified)	222	.8215	...
Sphecidae	76	.2812	3.2019
Bembecidae	4	.0148	2.5986
Sphecoidea (further unidentified)	23	.0851	...
Halictidae	134	.4958	.9745
Andrenidae	92	.3404	2.4594

Identifications of Hymenoptera—Continued

Family	Number of identifications	Percentage of identifications among those of all Hymenoptera	Percentage of species of this family among the whole number of species of these groups in New York State
Panurgidae	2	.0074	.3248
Nomadidae	12	.0444	.8817
Euceridae	10	.0370	...
Anthophoridae	4	.0148	.5568
Hylaeidae	1	.0037	.3248
Colletidae	8	.0296	.3248
Megachilidae	18	.0666	1.6241
Ceratinidae	2	.0074	.0464
Stelidae	1	.0037	.0928
Xylocopidae	2	.0074	.0464
Apidae	130	.5143	.8353
Apoidea (further unidentified)	372	1.3765	...
Unidentified	10,682	30.5266	...

Examination of the preceding tabulation shows again the influence of availability upon choice of food. It is at once evident that the groups more numerous in species and individuals are taken most often by birds. Whether all are taken in sufficient number to satisfy expectations is subject to discussion but the relativity of capture to abundance is unmistakable. Superfamilies such as the Cynipoidea and Chalcidoidea, owing to the minute size of most of their species, could not be expected to figure largely in the diet of birds, and the same is true for most Serphoidea. These are just the groups and the only ones in the table except the Sphecoidea that seem obviously to be inadequately represented. The Sphecoidea perhaps verge toward the opposite limit of size for bird food.

Since so many Hymenoptera were determined no further than to the order, the number of species (over 300) of birds eating these unidentified forms may be taken as an approximation to the entire number of bird species consuming Hymenoptera. It is enough at any rate to indicate that Hymenoptera are eaten by birds of all groups studied, just as the total number of records (over 27,000) of Hymenoptera clearly shows that these insects are one of the most important elements of bird food.

Beginning our consideration of the Hymenoptera with the sawflies, it may be said that some of these insects are alleged to obtain protection from their resemblance to stinging members of the order. As

to the larvae, Poulton says: "Numerous experiments have convinced me that the latter are almost invariably distasteful." (Essays on evolution, p. 238, 1908.) However, the present tabulations reveal more than 30 species of birds as predators upon sawfly larvae and no fewer than 50 to 100 specimens of these larvae have been found in single stomachs of the mockingbird and from 10 to 25 in those of other species. Hewitt records seven species of British birds as feeding upon larvae of the large larch sawfly (*Nematus erichsonii*) (Bull. 10, Div. Ent. Dom. Can. Dep. Agr., p. 22, 1912), and attributes to them great destruction of the larvae. The 380 records of Tenthredinoidea in our table are distributed among 99 species of birds and such wasp-suggesting forms as *Cimbex,* and the horntails of various kinds, with 24 records, seem to be proportionally represented.

Most of the Ichneumonoidea are not credited with any special defenses besides their resemblance to stinging hymenoptera, and the more than 1,200 records of their being eaten would seem to indicate that this means of protection is more imaginary than real. Some of the more interesting records may be cited as indicating the extent to which birds eat these insects: *Protapanteles:* 50 specimens in the stomach of an English sparrow (one of a series of 12 containing 10 or more each), and 120 in one stomach each of a Brewer's blackbird and an Aleutian sandpiper; Ichneumonidae, further unidentified: 68 specimens in a sanderling's stomach (19 birds have from 10 to 42 records each); *Ichneumon* sp.: 37 specimens in the stomach of a burrowing owl; *Glypta tuberculifrons:* 44 individuals taken at a meal by a yellow-throated vireo; *Ophion* spp.: 54 records for these large ichneumons which can sting.

Most ants, their size considered, can bite severely; their body fluids contain formic acid and other pungent substances; and many of them also can sting. As further tribute to their prowess the reference of Poulton may be quoted to the "numerous mimetic resemblances to the aggressive, abundant, and well-defended ants." (Essays on evolution, p. 252, 1908.) Badenoch says that ant-models "as a rule are exempt from persecution." (Romance of the insect world, p. 300, 1893). The confidence of selectionists in the protective nature of ant mimicry is further shown in the following statement by Donisthorpe on *Nabis lativentris:* "I consider this insect to be an ant mimic in its earlier stages, when it is usually found in the company of ants. From this mimicry it obtains protection from outside enemies, both as much when away from ants as when with them." (Ent. Monthly Mag. 3rd ser., vol. 7, pp. 137-138, 1921.)

But why this conclusion? The more than 12,000 records of ant-eating by the birds represented in our tabulations certainly indicate no sort of immunity on the part of ants from the attacks of birds. These records are shared by well over 300 species of birds which, practically speaking, means that all birds eat ants. Ninety-three of the species of birds represented in our tabulations have from 10 to 49 records of ant-eating each, 18 others from 50 to 99, 17 others from 100 to 199, four additional over 300, and one additional species, the eastern flicker, in excess of 500. All these records are among the Formicoidea further unidentified, three-fourths of the total for all ants. From 200 to 300 ants at a meal is a common number; the swallows often get 800 or more; the nighthawk 1,000; and woodpeckers 2,000 or more. In two cases stomachs of flickers yielded more than 3,000 ants each, and in one case more than 5,000. Out of 684 stomachs of this last named species, 524 contained ants.

In this connection the extent to which ants enter into the diet of certain birds is of considerable interest; our five species of thrushes of the genus *Hylocichla* consume ants to an average of 12.65 per cent of their total food, while 16 species of woodpeckers, the food of which was tabulated by Prof. F. E. L. Beal, ate ants to extents varying from 5 to 85 per cent of their entire subsistence, the average for the 16 species being 28.49 per cent.

The stinging ants, of course, are the most highly "protected" of all and it is unfortunate for our discussion that the group is so poorly represented in the United States. Myrmicidae, including Ponerinae and Dorylinae, are more or less generally provided with stings, which however in the most of our species are too small to inflict damage on a human subject. Our tabulations show 1,200 records for Myrmicidae, and they are eaten in just as large numbers as are other ants. The harvester ants of the genus *Pogonomyrmex* are larger and equipped with stings which can painfully wound a human being. We have 66 records of these ants being taken by 25 species of birds; no fewer than 200 and 400 individuals were taken from the stomachs of two Texan nighthawks. Mitchell and Pierce write of birds feeding freely on *Pogonomyrmex* and note a case of a group of nesting jackdaws (*Megaquiscalus*) cleaning up a colony in a short time. (Proc. Ent. Soc. Washington, vol. 14, no. 2, p. 72, June, 1912.)

Among the remaining, mostly stinging, Hymenoptera are the Chrysididae, supposed to be protected by their hardness, abililty to roll into a ball, and by metallic colors. We have 61 records of these being eaten, shared by 37 species of birds. The Vespoidea or wasps

as a whole have 822 records representing 140 species of birds. Some of the larger numbers of wasps consumed at a meal were 10 *Vespula germanica* by a wild turkey, 10 *Polistes* sp. by a yellow-billed magpie, and the following numbers of unidentified wasps by the birds mentioned: purple martin 17, olive-sided flycatcher 24, and kingbird 30.

The 103 records of Sphecoidea are distributed among 43 species of birds, none of which took any notable number of these large insects. Bees all sting, and the 797 records of their being eaten by the birds examined by us would seem to indicate considerable disregard for the stings on the part of birds. The number of species of birds represented in these bee-eating records is 144. Thirty-two species of birds took honey bees (*Apis mellifera*) on a total of 118 occasions and nine species of birds ate bumble bees a total of 18 times. These numbers of determinations seem in fair proportion to the availability of the bees concerned. The largest numbers of bees taken at a meal were 26 Andrenidae by a rose-breasted grosbeak, 34 honey bees by a cactus wren, and 106 of the domestic species by a road-runner.

It is of interest to note that besides the thrushes and woodpeckers previously mentioned, two other groups of birds are very notable consumers of Hymenoptera. Thus the seven species of swallows make an average of 24.9 per cent of their diet of these insects, and 14 species of flycatchers average 33 per cent.

Summary.—Number of identifications of Hymenoptera 27,025; percentage of identifications among those of all insects, 14.1551; percentage of species in this group among all insect species, 17.1798.

Other enemies.—Hymenoptera, having so few aquatic representatives, do not figure in the diet of fishes as anything but an incidental item, consisting of specimens, a considerable proportion of them ants, that have approached too near or have fallen upon the surface of the water.

Passing to batrachian enemies of Hymenoptera we may note that Kirkland found ants to compose 19 per cent of the contents of 149 toad stomachs, and that he had evidence also of their feeding extensively upon honey bees. Garman also found not only the common toad (*Bufo lentiginosus*) but also the pigmy toad (*Bufo quercicus*) to be very fond of ants. Toads have been observed to feed freely upon the larger stinging insects also, such as yellowjackets and wasps. Drake found 25 ants and 21 other Hymenoptera in 209 stomachs of the leopard frog. Insects of this order, especially ants, are eaten by all frogs and toads and to a considerable extent by salamanders also. Most lizards feed freely on ants, bees, and wasps. Winton found agricultural ants (*Pogonomyrmex*) in 80 per cent of the horned-toad

stomachs (485) examined by him, and Mitchell and Pierce record the extermination of a colony of these ants by horned-toads. Several species of snakes and a few turtles feed to a slight extent upon Hymenoptera.

Among mammals, moles prey extensively upon ants, and shrews and bats by no means avoid them. In our country armadillos are destructive ant eaters and in other continents various mammals specialize upon ants. Spermophiles and other slightly insectivorous rodents include ants and other Hymenoptera in their bill-of-fare. Skunks are assiduous in digging out the nests of yellowjackets (*Vespula*), the comb, its contents and active inhabitants of the nest all being devoured. Mice, weasels, foxes, and especially badgers similarly ravage the nests of bumble bees, while bears plunder not only these insects but also honey bees and hornets. Meadow mice and shrews have been found to be among the most effective enemies of sawflies, extracting the larvae from the cocoons, and these and deer mice take a heavy toll of the Hessian fly, nibbling the stem-galls and devouring their inmates. Squirrels feed freely upon galls produced by Hymenoptera.

The insect enemies of Hymenoptera are numerous and effective and strangely enough many of them are within the ranks of the order. Philanthidae use Aculeates for food, many bees, cuckoo wasps, and the like live parasitically in the nests of other Hymenoptera; the surprising phenomena of hyper-parasitism reveal numerous serious enemies of Hymenoptera among their own kin; and a number of dipterous parasites of sawflies, bees, and wasps are known. The so-called guests in the nests of bees and ants destroy many of the larvae of their hosts. Predacious insects such as assassin bugs, Phymatidae, dragonflies, and robber flies feed freely upon Hymenoptera, the last-named foes almost appearing to have a preference for the larger and better armed sorts of stinging Hymenoptera. Spiders of certain species entrap and devour large numbers of Hymenoptera. Nematode and protozoan parasites exist and some Hymenoptera have important fungal and bacterial diseases.

Discussion.—According to selectionists, Hymenoptera are the most highly protected insects and the so-called mimicry of examples of this order, such as the ants, by numerous spiders, long-horned beetles and rove beetles, plant-bugs, and other insects is regarded as strong evidence for the truth of the claim. Let the case be presented in the words of an advocate (Poulton, Essays on evolution, p. 260-261, 1908): "The means by which the resemblance to ants is brought about are diverse, the end—the resemblance itself—is uniform. Further-

more the likeness is almost always detailed and remarkable, however it is attained, while the methods made use of differ absolutely. . . . . We are compelled to believe that there is something advantageous in the resemblance to an ant, and that Natural Selection has been at work. The phenomena do not merely disprove all other suggested causes of change; they constitute the most powerful indirect proof of the operation of Natural Selection."

If the above reasoning has any application so far as the attacks of predators upon ants are concerned, we should expect some evidence that ants are relatively free from such attacks. Let us see what is the case. Beginning in the very homes of the ants we find, among creatures habitually living in ant colonies, that numerous Staphylinid beetles devour the brood, besides crippled and even normal ants; the larvae of Clythrinae (Chrysomelidae) feed on the eggs; lycaenid caterpillars and paussid beetles eat the eggs and larvae. Numerous ectoparasitic mites and some chalcidids also attack the ants in their domiciles, as well as entoparasites among the Strepsiptera, Phoridae, Conopidae, Braconidae, Chalcididae, Proctrotrupidae, and Nematoda. Ants have very important predatory enemies in their own ranks, namely the doryline and slave-making ants. Ant-lions of the family Myrmeleonidae, Diptera with similar habits, predacious wasps, especially the Crabronidae, assassin bugs, ground and tiger beetles, and spiders are serious invertebrate enemies of ants. Most toads, frogs, and lizards, the amphisbaenids, and certain snakes feed upon ants; fishes take them when opportunity affords; practically all birds eat ants, several groups as the song thrushes, ant-thrushes (Formicariidae), and woodpeckers depending upon them for a large part of their food; in the same way most of the insectivorous mammals are fond of ants and several groups of this phylum are specialized ant eaters, namely Echidnidae (spiny anteaters) among the Monotremata, the banded anteater (*Myrmecobius*) among the Marsupialia, and nearly the whole order of Edentata (antbears, pangolins, and armadillos).[1]

In fact it would be difficult to name a group of insects that is so thoroughly preyed upon as the ants, and impossible to name one that has so many specialized foes scattered through the various animal phyla. So far as predatory attack is concerned, it would seem that ant-mimics court rather than avoid danger. To recapitulate: if there is any virtue in the protective adaptations of the "aggressive, abun-

[1] For a comprehensive account of "The predacious enemies of ants," see Bequaert, Bull. Amer. Mus. Nat. Hist., vol. 45, pp. 271-331, 1922.

dant, and well-defended ants," it should be apparent in some lessening of predatory attacks upon them. However the very opposite is true and the case affords the best sort of proof of the thesis of this paper, namely that the number of enemies, or perhaps better stated, the total losses to enemies, is in direct proportion to abundance of the group concerned.

Selectionists regard bees as very highly protected insects, but taking the honey bee as type of the group because more is known about the species than any other, we find that bee-keepers complain bitterly of the numerous enemies of the inmates of their hives. Wasps, velvet-ants, robber flies, Phymatid bugs, mantids, and dragonflies are serious insect enemies of honey bees; spiders, toads, lizards, rats, mice, and skunks prey upon them; numerous wild birds join in the attack (32 nearctic species according to our tabulations), and domestic ducks are said to be insatiable in devouring bees. A mite is the primary cause of the so-called Isle-of-Wight disease among hive-bees; ants and wax moths destroy the comb; and there are at least two serious infectious diseases. At times bees rob other colonies, the rifling being accomplished however only after great slaughter. In the case of the honey bee, much study has been devoted to the insect and we know considerable about its enemies, but the ruling principle is as clear in this case as in that of the ants, namely, that common species have numerous enemies.

Since ants and the honey bee fairly exemplify two of the main phases of protective adaptation in Hymenoptera, despite which these species clearly have their full quota of enemies, we cannot doubt that other species of the order, when they are as well known, will prove to have predatory foes fully in proportion to their relative abundance.

In fact the 27,000 records of Hymenoptera now available are sufficient indication that the order contributes its due toll to the subsistence of one of the chief groups of its enemies—the birds.

Arachnida (Scorpions, Spiders, Ticks, Etc.)

Protective adaptations.—Most arachnids possess venom of sufficient strength, and means of injecting it into other creatures, to enable them to overcome the animals upon which they prey. Numbers of them have chelicerae, which in a few cases are rather powerful. The poisonous nature of many of the species has been greatly exaggerated especially by primitive races of man so that they are held in extreme dread.

Besides these direct means of defense, ticks and spiders exhibit in a high state of development that class of protective adaptations known as cryptic coloration (both defensive and aggressive). Certain groups, however, are brilliantly colored; some spiders also have the body integuments hardened and produced in the form of angles or spines, and numerous spiders resemble ants. Among the forms of this class ordinarily coming to the attention of man, spiders are by far the most numerous, but the small often minute mites prove, when the care necessary to their study is bestowed, to be exceedingly abundant. However, these small forms are beneath the notice of most birds.

The following table shows the relation of the records of the various orders to their approximate representation by species in the nearctic region.

Identifications of Arachnida

Order	Number of identifications	Percentage of identifications among those of all Arachnida	Percentage of species in this order among all nearctic Arachnida [1]
Unidentified	26	.2386	...
Xiphosura	20	.1836	.0513
Microthelyphonida	...	...	.0513
Scorpionida	18	.1652	1.1801
Pseudoscorpionida	80	.7343	2.4115
Pedipalpida	4	.0367	.3078
Solpugida	24	.2203	.6157
Phalangida	478	4.3873	3.4376
Araneida	9,966	91.4729	66.7044
Acarina	258	2.3681	23.0886
Pycnogonida	11	.1010	2.1549

Bird enemies.—Birds certainly specialize upon the group of arachnids—spiders—that to man seems most abundant and easily available, over 91 per cent of their arachnid captures coming from this order. We have records of more than 300 species of nearctic birds feeding on spiders. The freedom with which they take these creatures is illustrated by the following citations of records; of those identified to the order alone or about 92 per cent of the total, 81 birds have from 10 to 49 captures each; 28 birds from 50 to 99; 15 from 100

[1] Computed from Comstock, J. H., The spider book, etc., 721 pp., 1912, with numbers of Arancida and Acarina approximated from the following works, respectively: Banks, N., Catalogue of nearctic spiders, U. S. Nat. Mus. Bull. 72, 80 pp., 1910, and Banks, N., A catalogue of the Acarina, or mites, of the United States, Proc. U. S. Nat. Mus., vol. 32, pp. 595-625, 1907.

to 199; two additional above 200; one more above 300; besides the following with greater numbers of records; English sparrow, 420; Eastern meadowlark, 425; crow blackbird, 621; starling, 631; and crow, 722. Some of the larger counts of spiders taken at a meal were 25 by a Say's phoebe, 33 by a greater yellow-legs, 46 by a wood duck, 58 by a Louisiana heron, 187 by a starling, and 300 by a hairy woodpecker.

A rather small proportion (less than 8 per cent) of spiders found in bird stomachs were identified, but results obtained along this line show the determinations are distributed to cryptically colored groups as the Epeiridae (30 records) and Thomisidae (28); more brilliant forms as the Attidae (158) and to the formidable Lycosidae (370), in a way that would indicate availability to be the principal factor in choice. There are two records of *Synemosina formica*, the most antlike of our spiders, a small and rather uncommon form that one would expect no more frequently regardless of its "protected" status. As noted in the last section, however, resemblance to an ant is no protection whatever against predators. There are 134 records of the cocoons or egg-cases of spiders being eaten showing that even these quiescent stages do not escape the birds. In bulk spiders do not ordinarily form any considerable percentage of the total food of birds, but the proportion runs as high as 6 per cent and 8 per cent of the annual diet in the case of certain song thrushes and petty flycatchers.

There are 34 records in our tabulations of ticks being eaten, and 224 of mites. Of interest in connection with the latter are the finding of 100 Parasitidae in the stomach of a red-eyed vireo; 320 mites further unidentified in the stomach of a pipit; 535 water mites in the gizzard of a green-winged teal, and 594 of the same group in the stomach of a pied-billed grebe.

Such geographically restricted and relatively uncommon forms as the scorpions, pedipalps, and solpugids, even though having only a small number of records each, would seem, nevertheless, to be amply represented, considering their availability. Pseudoscorpions are present throughout our area but lead chiefly concealed lives; the 80 records are distributed among 22 species of birds.

The daddy-long-legs, or Phalangida, with 478 determinations certainly have not been slighted; 10 of the birds taking them have 10 to 19 records each; two others over 20 records; and one each additional, the yellow-billed cuckoo, 34; and crow blackbird, 60. Large numbers

of the arachnids captured for one meal were 20 by a yellow-billed cuckoo and 77 by an ovenbird.

Number of identifications, 10,885; percentage of identifications among those of all arthropods, 5.1648; percentage of species in this class among those of all arthropods, 3.8254.

Other enemies.—Spiders are frequently snapped up by fresh-water fishes, and mites often, especially the water mites. Pycnogonids, or sea-spiders, have occasionally been found in the stomachs of marine fishes and are consumed also by sea-anemones. Kirkland found spiders to compose 2 per cent of the food of 149 common toads examined by him, and Drake found them to constitute about 27 per cent of the entire number of animals found by him in the stomachs of 209 leopard frogs. However, practically all frogs, toads, and salamanders that have been studied have been found to feed upon spiders, often extensively, and mites, pseudoscorpions, and phalangids are not neglected. Lizards commonly prey upon spiders, while snakes and turtles so far have rarely been observed to do so.

Spiders appear to constitute an important element of the food of our shrews, and a lesser, though frequently taken, item in the diet of the moles. We have records of the wood rat and armadillo preying upon spiders, and evidence that the badger at times is a destructive enemy of scorpions. Monkeys and marmosets are said to be very fond of spiders, and anteaters also are listed among their foes.

Of invertebrate enemies various wasps (Pompilidae, Sphegidae, and Trypoxylonidae) are among the most effective destroyers of spiders, some species preying exclusively upon them, temporarily at least, even upon single species. The writer has found the cells of *Pelopaeus cementarius* filled entirely with flower spiders, *Misumena americana*, supposedly one of the most perfectly protected (cryptically colored) species. Dragonflies prey upon spiders. Tiger beetles and ants eat spiders and mites, ground beetles and ladybirds also figure as enemies of mites and spiders. Water mites are preyed upon by dragonfly nymphs and aquatic Hemiptera. There are a number of kinds of spiders that habitually prey upon their fellows when adult, and cannibalism among young spiders is the rule. Mantispidae and other spiders eat the eggs and young of spiders, and there are many proctotrupid and ichneumonid parasites of the eggs. Parasitic nematodes also afflict the adults. Scorpions are notoriously cannibalistic, so much so in fact that it is said in some cases that whenever two of them are found together, one is eating the other.

Discussion.—All spiders have venom and some of them are large and venomous enough to be able to kill birds. The case would seem to be crucial for the usefulness of this direct means of defense, but we may well say, in the light of the evidence, that the defense is entirely disregarded by birds. Not only do our records show more than 10,000 records of spiders having been eaten by more than 300 species of birds, but the birds emphasize their disregard for the dangerous qualities of spiders by making them in many cases the staple food for their callow young. Such minor protective adaptations as those of color and form necessarily fall with the greater, and there is no evidence whatever but that birds eat spiders under any and all conditions as freely as they choose. The nearly 1,000 records of arachnids other than spiders seem to be distributed among the orders in very just proportion to the extent these creatures are available to birds. No evidence of "special protectedness" obtrudes itself.

MOLLUSCA (SNAILS, SLUGS, MUSSELS, LIMPETS)

Protective adaptations.—The great majority of mollusks are equipped with calcareous shells into which they can entirely withdraw. Besides this protection more than half of the species are aquatic and hence are more or less out of reach of many birds. Many land snails have the apertures of their shells furnished with processes or teeth which partly bar these openings and operculi to close them. Snails and especially slugs secrete mucus freely: a habit thought by some to be protective. Numerous mollusks are colored more or less in harmony with their environments, this being especially noted of marine forms living on seaweeds, gorgonians, etc. The nudibranch mollusks are characteristically brightly colored and have been said to be distasteful. Of shelled mollusks, Wallace remarks: "The brilliant colors of the scallops (*Pecten*) and some other bivalve shells are perhaps an indication of their hardness and consequent inedibility." (Darwinism, p. 266-267, 1896.)

Bird enemies.—The tabulation of identifications herewith presented is the best that could be made so far as comparative records is concerned; these had to be gleaned from two sources as noted, which between them do not include all of the families, nor, because of disparity of data, do they give even the grand divisions comparable treatment.

Identifications of Mollusca

Aquatic shells

Group	Number of identifications	Percentage of identifications among those of all Mollusca	Percentage of species in this group among marine mollusks of the Southeast Coast [1]
Unidentified	1,032	8.7673	...
Pelecypoda (further unidentified)	513	4.3582	...
Ostreidae	552	4.6895	.2516
Anomiidae	...	...	.1887
Dimyidae	...	...	.0629
Spondylidae	...	...	.1887
Pectinidae	193	1.6396	1.8868
Limidae	...	...	.6918
Aviculidae	...	...	.5031
Mytilidae	674	5.7260	1.6353
Unionidae	8	.0679	...
Arcidae	73	.6201	2.0755
Nuculidae	45	.3823	.6289
Ledidae	1	.0085	1.9497
Solenomyidae	1	.0085	.1887
Carditidae	...	...	.4402
Astartidae	20	.1699	.6918
Crassatellidae	...	...	.1887
Erycinidae	2	.0170	.5031
Ungulinidae	...	...	.6289
Cyrenellidae	...	...	.0629
Lucinidae	...	...	1.4465
Diplodontidae	...	...	.2516
Chamidae	...	...	.3145
Cardiidae	20	.1699	.8176
Veniliidae	2	.0170	.0629
Isocardiidae	...	...	.1887
Veneridae	131	1.1129	1.9497
Corbiculidae	...	...	.1258
Petricolidae	28	.2378	.4402
Donacidae	122	1.0364	.3773
Psammobiidae	...	...	.3773
Tellinidae	324	2.7525	2.3270
Semelidae	...	...	.6289
Gnathodontidae	4	.0340	.1258
Mactridae	21	.1784	.3145
Anatinidae	...	...	.8176

[1] Compiled from Dall, W. H., A preliminary catalogue of the shell-bearing marine mollusks and brachiopods of the southeastern coast of the United States, with illustrations of many of the species, U. S. Nat. Mus. Bull. 37, 221 pp., 74 pls., 1889.

Identifications of Mollusca—Continued

Aquatic shells

Group	Number of identifications	Percentage of identifications among those of all Mollusca	Percentage of species in this group among marine mollusks of the Southeast Coast
Lyonsiidae	...	...	.4402
Verticordiidae	...	...	.6289
Cuspidariidae	...	...	1.1321
Poromyidae	...	...	.5031
Pandoridae	...	...	.3145
Corbulidae	92	.7716	.6918
Myidae	10	.0849	.0629
Saxicavidae	25	.2124	.1887
Paphiidae	400	3.3982	...
Solenidae	4	.0340	.3145
Gastrochaenidae	...	...	.2516
Pholadidae	...	...	.7547
Teredidae	5	.0425	.5031
Gastropoda (further unidentified)	3,421	29.0631	...
Dentaliidae	1	.0085	2.7673
Limacinidae	...	...	.6289
Cavoliniidae	...	...	1.1950
Cymluliidae	...	...	.0629
Clionidae	...	...	.0629
Cliopsidae	...	...	.1258
Pneumodermatidae	...	...	.0629
Actaeonidae	...	...	.6289
Ringiculidae	...	...	.1258
Tornatinidae	77	.6541	1.2207
Scaphandridae	...	...	.5660
Aplustridae	...	...	.1258
Bullidae	...	...	.6918
Philinidae	...	...	.3373
Gastropteridae	...	...	.0629
Umbraculidae	...	...	.1258
Aplysiidae	...	...	.1258
Pleurobranchidae	...	...	.1887
Onchidiidae	...	...	.0629
Veronicellidae	...	...	.0629
Auriculidae	158	1.3423	1.0063
Siphonariidae	...	...	.1887
Gadiniidae	...	...	.0629
Terebridae	1	.0085	.6289
Conidae	...	...	.6918
Pleurotomidae	43	.3653	8.3019
Cancellariidae	...	...	.5031
Olividae	11	.0934	.5031

Identifications of Mollusca—Continued

Aquatic shells

Group	Number of identifications	Percentage of identifications among those of all Mollusca	Percentage of species in this group among marine mollusks of the Southeast Coast
Marginellidae	7	.0595	2.9560
Volutidae	...	...	.3145
Turbinellidae	...	...	.1258
Mitridae	...	...	1.0692
Fasciolariidae	18	.1529	1.6981
Buccinidae	7	.0525	1.9497
Nassidae	424	3.6021	.5031
Columbellidae	346	2.9394	1.6352
Muricidae	111	.9430	2.6415
Scolidae	...	...	3.3962
Janthinidae	...	...	.2516
Eulimidae	2	.0169	1.0692
Pyramidellidae	176	1.4952	3.3333
Tritoniidae	...	...	1.0063
Oocoritidae	...	...	.1887
Cassidae	...	...	.5031
Doliidae	...	...	.3145
Amphiperasidae	...	...	.3773
Cypraeidae	...	...	.6918
Carinariidae	...	...	.5031
Strombidae	...	...	.3145
Triforidae	17	.1444	1.0063
Cerithiopsidae	4	.0340	.6918
Cerithiidae	218	1.8520	1.0063
Planaxidae	...	...	.1258
Modulidae	2	.0169	.0629
Trichotropidae	13	.1104	.1887
Caecidae	7	.0595	.8176
Seguenziidae	...	...	.3145
Vermetidae	...	...	.5031
Turritellidae	2	.0169	.3145
Mathildiidae	...	...	.3145
Litorinidae	564	4.7915	.6918
Fascaridae	...	...	.2516
Litiopidae	...	...	.1887
Solariidae	...	...	.8176
Rissoidae	67	.5692	1.5094
Adeorbidae	...	...	.3145
Limacidae	2	.0169	...
Philomycidae	1	.0085	...
Ampullariidae	4	.0340	.1258
Assimineidae	11	.0934	.1887
Cymatidae	1	.0085	...

Identifications of Mollusca—Continued

Aquatic shells

Group	Number of identifications	Percentage of identifications among those of all Mollusca	Percentage of species in this group among marine mollusks of the Southeast Coast
Truncatellidae	...	...	.2516
Choristidae	...	...	.0629
Calyptraeidae	135	1.1469	.5031
Capulidae	...	...	.1887
Amaltheidae	...	...	.1887
Xenophoridae	...	...	.1258
Naticidae	47	.3993	1.5094
Lamellariidae	...	...	.1887
Acmaeidae	43	.3653	.3145
Lepetidae	...	...	.2516
Scutellinidae	...	...	.0629
Addisoniidae	...	...	.0629
Cocculinidae	...	...	.3773
Phasianellidae	...	...	.1887
Turbinidae	...	...	.8176
Trochidae	18	.1529	3.9622
Delphinulidae	...	...	.6289
Cyclostrematidae	...	...	.8805
Neritidae	374	3.1773	.5031
Stomatiidae	...	...	.0629
Haliotidae	...	...	.0629
Scissurellidae	...	...	.1887
Pleurotomariidae	...	...	.1258
Tissurellidae	...	...	2.2012
Chitonidae	26	.2209	1.4465
Cephalopoda (further unidentified)	86	.7306	...
Loliginidae	3	.0254	.1258

Land shells

Family	Number of identifications	Percentage of identifications in this group among those of all land Mollusca (except the unidentified)	Percentage of species in this group among all nearctic land Mollusca [1]
Cyclostomatidae	...	...	.5277
Truncatellidae	...	...	1.0554
Helicinidae	14	7.9096	1.0554
Helicidae	70	39.5479	37.7305

[1] Compiled from Pilsbry, H. A., and Johnson, C. W., A classified catalogue with localities of the land shells of America north of Mexico. Reprinted from The Nautilus, 1897-1898, Philadelphia, 35 pp., 1898.

Identifications of Mollusca—Continued

Land shells

Family	Number of identifications	Percentage of identifications in this group among those of all land Mollusca (except the unidentified)	Percentage of species in this group among all nearctic land Mollusca
Bulimulidae	...	...	2.9023
Urocoptidae	...	...	4.2216
Pupidae	42	23.7287	13.1925
Achanitidae	1	.5649	1.5831
Glandinidae	...	...	1.0554
Testacellidae	...	...	.2638
Circinariidae	...	...	1.8469
Zonitidae	27	15.2542	17.6779
Limacidae	2	1.1299	1.5831
Arionidae	...	...	3.6939
Philomycidae	1	.5649	1.3192
Endodontidae	6	3.2898	4.2216
Succineidae	14	7.9096	5.8047
Vaginulidae	...	...	.2638

The outstanding impression given by the foregoing table is that notwithstanding their relatively low availability to birds, mollusks of practically all kinds are eaten. In general it is also true that the large groups more numerous in species and individuals contribute most heavily to avian subsistence, while the small groups of less abundance get off with a light toll.

Let us see what are the relations of birds to some of the protected mollusks. In a paper "On the Adaptive Coloration of Mollusca" (Proc. Boston Soc. Nat. Hist., vol. 14, pp. 141-145 (1871) 1872), Edward S. Morse alludes to protective coloration of several species. His remarks with comment deduced from our tabulations are herewith presented. "Among the marine forms we notice the adaptive coloration of certain species very well marked. The common *Littorina* of the coast swarms on the bladder weed, the bulbous portions of which are olive brown in color or yellowish according to age. The shells of the *Littorina* found upon it, present in their varieties these two colors and are limited to these colors" (p. 143). Our tabulations show 503 records of capture of *Littorina*, 11 species of which were identified from the stomachs of 46 kinds of birds. These shells are freely eaten as the following instances of large numbers taken by single birds testify: Pacific eider 110, surf scoter 120, black duck 150, purple sandpiper 205, and greater scaup duck 350.

"The few species common to the mud flats exposed by the retreating tide are colored black or dark olive." Examples: *Ilyanassa obsoleta, Nassa trivittata, Rissoa minuta* (p. 143). There are 78 records of *Ilyanassa obsoleta* distributed among 18 species of birds. Thirty-two of these shells were taken at a meal by a greater scaup duck, and from 42 to 62 by each of six knots. There are 98 records of *Nassa trivittata*, two of them being 275 and 285 specimens in the stomachs of greater scaups; and there are three determinations of *Rissoa minuta*.

Lacuna vincta: The colors "quite match the Laminarian upon which they are found" (p. 143). This species was identified 39 times in nine species of birds in which numbers from 32 to 75 were found, and in one case, that of a golden-eye, no fewer than 116.

"*Margarites helicina* I have found in numbers on the large Laminarian and on seaweed at low water mark and its color is decidedly protective" (p. 144). Our tabulation shows 10 records of this species of shell, distributed among five kinds of birds.

"A very evident case of protective coloring is seen in the three species of *Crepidula* found on our coast. *Crepidula fornicata* is drab, variously rayed and mottled with brown, and it lives attached to stones near the roots of the large Laminarian or upon stones clothed with algae of similar colors, or attached to the large *Mytilus*. *Crepidula convexa*, a much smaller species, lives on the roots of seaweed. Professor Perkins records its occurrence on the black shell of *Ilyanassa obsoleta*. This *Crepidula* has a very dark brown shell, according well with the dark color of its various places of lodgement. *Crepidula plana* or *unguiformis* lives within the apertures of the shells of larger species of Gasteropods, as *Buccinum, Natica, Busycon* and others. The shell of this *Crepidula* is absolutely white" (pp. 144-145).

All of the limpets named in the foregoing quotation have been identified from the stomachs of nearctic birds, and the total number of records for species of *Crepidula* is 135. Fifty specimens of *C. glauca* were found in one gizzard of a greater scaup duck and 60 in another. The "protection" of *C. plana* is very undependable since all of the mollusks named as its hosts are swallowed whole by birds and other predatory enemies of shellfish. With reference to a special enemy of limpets "it has been calculated that a single flock of oystercatchers, frequenting a small Scotch Loch, must consume hundreds of thousands of limpets in the course of a single year." (Cooke, Cambridge Nat. Hist., vol. 3, pp. 56-57, 1895.)

As an example of the land snails thought to be defended from some enemies by the toothed apertures of their shells, the genus *Polygyra*

may be mentioned. Twelve species have been identified from the birds represented in our tabulations, the total number of determinations being 42. Slugs were identified three times, but our findings in this respect probably are not representative since in Great Britain it is said that: "Every kind of slug and snail is eaten greedily by blackbirds, thrushes, chaffinches, and in fact by many species of birds." (Cooke, Cambridge Nat. Hist., vol. 3, p. 58, 1895.) With regard to highly colored shells, such as *Pecten*, conjectured by Wallace to be protected, it may be said that our table shows 193 records for *Pecten* and the Biological Survey has been called upon to make a special study of damage to the scallop industry by wild fowl in the vicinity of Marthas Vineyard, Mass. Teredos were identified from the stomachs of four Bachman oyster-catchers and of one egret.

It should be remarked that the very large number of records of Ostreidae in the tabulations is due also to a special investigation of the bird enemies of *Ostrea lurida*. The high records for Tellinidae (*Macoma*, especially) and Paphiidae (*Paphia staminea*) are chiefly by-products of this same study. The large numbers of identifications for such dominant families as the Mytilidae, Nassidae, Columbellidae, and Litorinidae among marine shells and Amnicolidae and Lymnaeidae among fresh-water ones, need no explanation.

Number of identifications, 11,771; percentage of identifications among those of all animals, 4.9583; percentage of species in this phylum among the whole number of animal species known, 10.8828.

Other enemies.—Mollusks are preyed upon to an important extent by very many marine fishes, as well as by most of the rays and sharks; among these being numerous forms specialized (as by possession of the pavement-like pharyngeal dentition) to feed upon shell fish. For such fishes as the haddock, cod, wolffish, and flounders they are a staple food. Field found razor-clams in 4 per cent of 388 stomachs of the smooth dogfish (*Mustelus canis*); and in 3.68 per cent of 516 stomachs of the summer skate (*Raja erinacea*). The same author found mollusks of various kinds in 17.64 per cent of the stomachs of 306 cunners (*Tautogolabris adspersus*), and in 27.2 per cent of those of 33 toadfish (*Opsanus tau*). Some of the marine fishes are known to be enemies of certain specially defended mollusks; as predators on *Crepidula*, the scup, tautog, swellfish and toadfish may be mentioned; upon chitons, the haddock and flounders (*Pleuronectes*); and upon *Eolis* and other nudibranchs, the cods, gurnards and flounders. Cephalopods, especially squids, are a favorite food of many of the highly predacious fishes as the sharks, rays, bonito, swordfish, bluefish, mackerels, pollock, and haddock. It would be easy to compile a

very long list of squid-eaters. As to the extent to which these cephalopods are taken, Field reports squid from the following percentages of the stomachs examined by him: Summer skate 6.39 per cent, smooth dogfish nearly 10 per cent, and goosefish 17.39 per cent. Cuttlefishes are known to be eaten by the bonito, cod, whiting, and gurnard, and octopods by the ling, haddock, and conger eel.

Turning to the fresh-water mollusks, we find that they are equally beset by enemies. Pearse reports 2 per cent of the total food of 32 species of fishes in Wisconsin lakes consists of these animals, and from Forbes we learn that mollusks make up about one-fourth of the food of the dogfish (*Amia*) and a sheepshead (*Aplodinotus*), about half that of the suckers (*Catostomus*), rising to 60 per cent in the case of the red-horse (*Xenorostoma*), and a considerable proportion (14 to 16 per cent) of the food of the perch (*Perca flavescens*), catfishes, sunfishes, top minnows, and shiner (*Abramis*). Almost all fishes eat mollusks to some extent and practically all groups of mollusks suffer from these predatory attentions.

Taking up the relations of amphibians to mollusks, it may be noted that Kirkland found 1 per cent of the food of 149 toads to consist of snails and slugs, and Drake found 29 of these mollusks in 209 stomachs of the leopard frog. In general it may be said that most frogs consume aquatic snails when in the larval state and land snails when adult. With reference to European conditions, Cooke adds: "Frogs and toads are very partial to land mollusca. A garden attached to the Laboratory of Agricultural Chemistry at Rouen had been abandoned for three years to weeds and slugs. The director introduced 100 toads and 90 frogs, and in less than a month all the slugs were destroyed." (Cambridge Nat. Hist., vol. 3, p. 58, 1895.) Snails are eaten by most salamanders, the kind, whether water or land, depending on the habits of the salamanders concerned; small mussels even are consumed by some of the thoroughly aquatic forms.

Reptiles do not prey very extensively upon mollusks, yet snails are frequently eaten by lizards; slugs and snails are eaten by several species of snakes and by most turtles, the aquatic forms of the latter group consuming some bivalves.

Among mammals we find that some of the land forms consume mollusks to a slight extent; shrews, rats, white-footed mice, squirrels, and chipmunks may be mentioned as examples; a specimen of the eastern chipmunk (*Eutamias striatus*) taken near Fairfax, Va., had packed in its cheek-pouches or swallowed more than 47 *Pomatiopsis lapidana*. It is well known that the muskrat preys extensively upon fresh-water mussels, and the mink and otter must be listed as foes of

fresh-water mollusks. The food of the walrus consists mainly of shellfish. Dyche reports that the California sea-lion feeds very largely upon squids and octopods and it is known that squids form a considerable proportion of the diet of sperm and other whales.

The enemies of marine mollusks include also sea-anemones, starfishes, and boring univalves of the genera *Purpura, Polynices, Thais, Lunatia, Natica, Cycotypus, Fulgur,* and *Urosalpinx.* Fresh-water mollusks form an important element of the food of dragonfly nymphs, and a lesser one of horse fly larvae, water beetle larvae, water bugs, leeches, and crayfishes. Land snails are attacked by predacious beetles and fly larvae. Mollusks also have enemies among such parasitic groups as mites, nematodes, and trematodes.

Discussion.—From the abundance of their enemies and from the extent to which these predators feed upon mollusks (more than 8,000 records for birds in our tabulations), it is evident that the possession of a shell as a means of defense has been entirely discounted so far as predators of any size are concerned. The relations of birds to the protectively colored forms show that some of these (Litorinidae) are freely eaten; the brightly colored shells (Pectenidae) also are freely taken, as well as the very hard and thick-shelled ones (Ostreidae). Slugs, snails, limpets, teredos, chitons, and cephalopods pay their toll also, testimony to the all-pervading search for food by birds. In fact the evidence is that birds feed more or less indiscriminately upon all mollusks of suitable size that are available to them. Other enemies follow mollusks, especially the marine forms, where most birds can not, and it would seem that the whole molluskan world is exploited as a source of food to as large an extent as could be expected.

CHORDATA (LANCELETS, TUNICATES, VERTEBRATES)

While the Chordata with 13,326 identifications contribute only 5.6133 per cent of the total determinations of the animal food of birds, yet the phylum comprises so many familiar animals that it probably will be best to treat it more in detail as was done in the case of insects.

Number of identifications, 13,326; percentage of identifications among those of all animals, 5.6133; percentage of species in this phylum among the whole number of animal species known, 8.8427.

A tabulation of the records of Chordata with frequency indices derived from estimates for the world fauna gives the following results:

Identifications of Chordata

Class	Number of identifications	Percentage of identifications among those of all Chordates	Percentage of species in this class among those of the whole number of Chordate species known
Urochorda	5	.0375	2.6228
Pisces	4,923	36.9427	26.2281
Amphibia	997	7.4816	4.4386
Reptilia	695	5.2153	12.1053
Aves	3,555	26.6771	40.3510
Mammalia	3,151	23.6454	14.1228

The urochordates listed are ascidians, in three cases being identified as *Boltenia ovifera*. While the identifications of urochords is far from proportional to the frequency of these animals, the result is only what would be expected in view of their strictly marine and chiefly submerged habitat in which they are exposed to the attacks of only a very small proportion of our birds. It may be noted here that tunicates have numerous enemies, however, among fishes which take the pelagic and both simple and colonial fixed ascidians. It is on record that these animals are not uncommon in the stomachs of cod and haddock, and they have been found also in herring, flatfishes, tilefish, cunner, scup, the great sunfish (*Mola*), and a number of other fishes. They are taken also by sea-anemones and sea-urchins.

Omitting the Urochorda and figuring frequency indices from the fairly well known numbers[1] of North American species in the various classes we obtain the following table:

Identifications of Vertebrata

Class	Number of identifications	Percentage of identifications among those of all Vertebrata	Number of nearctic species in this class	Percentage of species in this class among those of all nearctic Vertebrata
Pisces	4,923	36.9565	3,054	61.3253
Amphibia	997	7.4844	141	2.8313
Reptilia	695	5.2173	308	6.1847
Aves	3,555	26.6870	801	16.0843
Mammalia	3,151	23.6542	676	13.5743

In this as in other cases we clearly observe the tendency for losses to predators to correspond to the extent and abundance of a group. In fishes the largest class are preyed upon the most, but less than their

[1] Counts derived from standard works on the various classes, as noted later in connection with the tabulations by classes.

relative abundance would seem to warrant, for the reason that, as a group, they are relatively inaccessible to birds, many of the deeper-water forms being entirely so.

Pisces (Fishes)

Protective adaptations.—It has been held that the great group of spiny-rayed fishes is protected from enemies to a greater degree than the soft-finned families, and in general harsh scales and spines are deemed protective. Some fishes have poison glands connected with certain specialized spines. Some of the species with disagreeable qualities have colors that are said to be warning, while the great majority of fishes exhibit varying degrees of cryptic coloration, many of them having more or less ability to change in color in response to that of their environment. Such in brief are some of the more or less theoretical defenses of fishes; as to actual physical protection, it may be said that fishes are shielded from most birds by their aquatic habits and many of them even from water birds by their living at considerable depths.

Bird enemies.—It is well known that whole families of the so-called lower orders of birds are specialized to prey upon fishes, for example the loons, terns, cormorants, anhingas, pelicans, mergansers, herons, and kingfishers. There are special fish eaters in other groups, and many birds not at all specialized to prey upon fishes nevertheless consume them to some extent more or less habitually. Nearctic birds which subsist almost exclusively upon fishes include: the western grebe, Caspian, royal and Cabot terns, black skimmer, anhinga, double-crested cormorant, brown and white pelicans, man-o'-war bird, and osprey. Others making fishes from 50 to 90 per cent of their diet are: the common loon, Holboell's grebe, black, Mandt's and pigeon guillemots, common and Brunnich's murre, kittiwake, glaucous-winged, herring, and ring-billed gulls, gannet, violet-green cormorant, American and red-breasted mergansers, bald eagle, and belted kingfisher.

Nearly 5,000 records of fishes being eaten are contained in our tabulations of the food of nearctic birds, and of these nearly half were identified no further than the class. The remaining determinations grouped by families are listed herewith:

Identifications of Pisces

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes [1]
Unidentified	2,253	45.7652	...
Branchiostomidae	...	...	.1310
Heptatremidae	...	...	.0327
Myxinidae	...	...	.0327
Petromyzonidae	...	...	.3274
Chlamydoselachidae	...	...	.0327
Hexanchidae	...	...	.0982
Heterodontidae	...	...	.0655
Scylliorhinidae	...	...	.1965
Ginglymostomidae	...	...	.0327
Pseudotriakidae	...	...	.0327
Galeidae	...	...	.9823
Sphyrnidae	...	...	.0982
Alopiidae	...	...	.0327
Carchariidae	...	...	.0327
Lamnidae	...	...	.1637
Cetorhinidae	...	...	.0327
Rhinodontidae	...	...	.0327
Squalidae	...	...	.1637
Dalatiidae	...	...	.0327
Echinorhinidae	...	...	.0327
Squatinidae	...	...	.0327
Pristidae	...	...	.0655
Rhinobatidae	...	...	.2947
Rajidae	...	...	.6221
Narcobatidae	...	...	.1310
Dasyatidae	...	...	.5239
Myliobatidae	...	...	.2619
Mantidae	...	...	.0655
Chimaeridae	...	...	.1310
Polyodontidae	...	...	.0327
Acipenseridae	...	...	.1965
Lepisosteidae	5	.1016	.1310
Amiidae	1	.0203	.0327
Siluridae	100	2.0313	3.1107
Loricariidae	...	...	.3274
Catostomidae	62	1.2594	2.1284
Cyprinidae	482	9.7909	7.3346
Erythrinidae	...	...	.0327
Characinidae	...	...	.6221
Apodes	2	.0406	...

[1] Computed from Jordan, D. S., and Evermann, B. E., The fishes of North and Middle America, etc., U. S. Nat. Mus. Bull. 47, 4 vols., 1896-1900.

Identifications of Pisces—Continued

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes
Gymnotidae	...	...	.0655
Symbranchidae	...	...	.0327
Derichtyidae	...	...	.0327
Anguillidae	16	.3250	.0327
Simenchelyidae	...	...	.0327
Ilyophidae	...	...	.0327
Synaphobranchidae	...	...	.0982
Leptocephalidae	...	...	.2619
Muraenesocidae	...	...	.4584
Nettastomidae	...	...	.0655
Nemichthyidae	...	...	.2292
Myridae	2	.0406	.1310
Ophichthyidae	1	.0203	.9496
Muraenidae	...	...	.9496
Saccopharyngidae	...	...	.0327
Eurypharyngidae	...	...	.0327
Elopidae	...	...	.0655
Albulidae	...	...	.0327
Hiodontidae	...	...	.0982
Chanidae	...	...	.0327
Dorosomidae, Clupeidae	249	5.0579	1.3097
Engraulididae	51	1.0360	.8841
Alepocephalidae	...	...	.3602
Salmonidae	198	4.0220	1.0478
Thymallidae	...	...	.0655
Argentinidae	30	.6094	.3929
Microstomidae	...	...	.1310
Synodontidae	2	.0406	.4257
Aulopidae	...	...	.1310
Benthosauridae	...	...	.0655
Bathypteroidae	...	...	.0655
Ipnopidae	...	...	.0327
Rondeletiidae	...	...	.0327
Cetomimidae	...	...	.0655
Myctophidae	...	...	1.4080
Maurolicidae	...	...	.0655
Chauliodontidae	...	...	.2947
Astronesthidae	...	...	.0982
Stomiatidae	...	...	.1965
Malacosteidae	...	...	.0327
Alepisauridae	...	...	.1637
Odontostomidae	...	...	.0327
Paralepididae	...	...	.1965

Identifications of Pisces—Continued

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes
Sternoptychidae	...	...	.0982
Idiacanthidae	...	...	.0655
Halosauridae	...	...	.2292
Notacanthidae	...	...	.1965
Lipogenyidae	...	...	.0327
Dalliidae	...	...	.0327
Umbridae	9	.1828	.0655
Luciidae	22	.4469	.1965
Poeciliidae	530	10.7659	3.8638
Amblyopsidae	...	...	.1310
Esocidae	8	.1625	.6221
Hemiramphidae	4	.0812	.2292
Scombresocidae	...	...	.0655
Exocoetidae	1	.0203	.6221
Gasterosteidae	111	2.2547	.2292
Aulorhynchidae	...	...	.0327
Aulostomidae	...	...	.0327
Fistulariidae	...	...	.0982
Macrorhamphosidae	...	...	.0327
Syngnathidae	6	.1219	1.1460
Percopsidae	...	...	.0655
Aphredoderidae	1	.0203	.0327
Atherinidae	38	.7719	1.1133
Mugilidae	18	.3656	.5566
Sphyraenidae	...	...	.1637
Polynemidae	...	...	.1637
Ammodytidae	25	.5078	.1310
Bathyclupeidae	...	...	.0327
Stephanoberycidae	...	...	.0655
Trachichthyidae	...	...	.0327
Berycidae	...	...	.3274
Holocentridae	...	...	.4584
Polymixiidae	...	...	.0327
Mullidae	...	...	.2619
Scombridae	1	.0203	.4912
Gempylidae	...	...	.2292
Lepidopidae	...	...	.1310
Trichiuridae	...	...	.0327
Istiophoridae	...	...	.0982
Xiphiidae	...	...	.0327
Nematistiidae	...	...	.0327
Carangidae	7	.1422	1.0074
Pomatomidae	4	.0812	.0327
Rachycentridae	1	.0203	.0327

Identifications of Pisces—Continued

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes
Nomeidae	...	...	.1637
Coryphaenidae	1	.0203	.0655
Lampridae	...	...	.0327
Pteraclidae	...	...	.0327
Bramidae	...	...	.1310
Steinegeriidae	...	...	.0327
Centrolophidae	...	...	.0655
Stromateidae	...	...	.1965
Icosteidae	...	...	.1310
Grammicolepididae	...	...	.0327
Tetragonuridae	...	...	.0327
Pempheridae	...	...	.1310
Elassomidae	...	...	.0655
Centrarchidae	164	3.3313	1.0478
Kuhliidae	...	...	.0655
Percidae	171	3.4735	2.8160
Cheilodipteridae	...	...	.4912
Centropomidae	...	...	.4257
Serranidae	5	.1016	3.0779
Lobotidae	...	...	.0327
Priacanthidae	...	...	.1310
Lutianidae	...	...	1.1133
Haemulidae	2	.0406	1.8009
Sparidae	5	.1016	.7858
Maenidae	...	...	.0655
Gerridae	3	.0609	.5566
Kyphosidae	...	...	.3929
Sciaenidae	14	.2844	3.5036
Cirrhitidae	...	...	.0655
Embiotocidae	7	.1422	.5894
Cichlidae	...	...	1.8337
Pomacentridae	...	...	.9823
Labridae	11	.2234	1.6044
Scaridae	...	...	1.4407
Zeidae	...	...	.0982
Caproidae	...	...	.0655
Ephippidae	...	...	.0982
Chaetodontidae	...	...	.6549
Zanclidae	...	...	.0327
Teuthididae	...	...	.2947
Triacanthidae	...	...	.0327
Balistidae	...	...	.5239
Monacanthidae	3	.0609	.3602
Ostraciidae	...	...	.1310

Identifications of Pisces—Continued

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes
Tetraodontidae	...	...	.6221
Canthigasteridae	...	...	.0655
Diodontidae	1	.0203	.3602
Molidae	...	...	.0655
Scorpaenidae	...	...	2.6523
Anoplopomatidae	...	...	.0655
Hexagrammidae	4	.0812	.3274
Cottidae	188	3.8188	4.2567
Ramphocottidae	...	...	.0327
Agonidae	2	.0406	1.1788
Cyclopteridae	...	...	.2947
Liparididae	...	...	1.2443
Triglidae	1	.0203	.8186
Peristediidae	...	...	.1310
Cephalacanthidae	...	...	.0327
Callionymidae	...	...	.1310
Gobiidae	10	.2031	2.8487
Echeneididae	...	...	.2292
Malacanthidae	...	...	.1637
Opisthognathidae	...	...	.3602
Bathymasteridae	...	...	.0982
Chiasmodontidae	...	...	.0655
Chaenichthyidae	...	...	.0327
Trichodontidae	...	...	.0655
Dactyloscopidae	...	...	.3274
Uranoscopidae	2	.0406	.1637
Batrachoididae	17	.3453	.3274
Gobiesocidae	1	.0203	.8841
Blenniidae	16	.3250	4.5187
Cryptacanthodidae	...	...	.0982
Anarhichadidae	1	.0203	.1965
Cerdalidae	...	...	.0982
Ptilichthyidae	...	...	.0327
Scytalinidae	...	...	.0327
Zoarcidae	...	...	1.0805
Derepodichthyidae	...	...	.0327
Ophidiidae	...	...	.5566
Lycodapodidae	...	...	.1310
Fierasferidae	...	...	.0982
Brotulidae	...	...	.8841
Bregmacerotidae	...	...	.0655
Merluccidae	...	...	.0982
Gadidae	31	.6297	1.1788
Macrouridae	...	...	1.0805

Identifications of Pisces—Continued

Group	Number of identifications	Percentage of identifications among those of all fishes	Percentage of species of this group among North American fishes
Regalecidae	...	...	.0327
Trachypteridae	...	...	.0982
Stylephoridae	...	...	.0327
Pleuronectidae, Soleidae	30	.6093	3.7983
Lophiidae	...	...	.0327
Antennariidae	...	...	.4912
Ceratiidae	...	...	.3274
Ogcocephalidae	...	...	.3274

Total number of identifications of fishes, 4.923; percentage of identifications among those of all vertebrates, 36.9565; percentage of species in this class among those of all nearctic vertebrates, 61.3253.

Commenting on this table it is obvious that a wide range of fishes is preyed upon, and that the families known to be most abundant in individuals almost invariably are those most extensively consumed by the birds. As to the bearing of this data on protective adaptations, we see the spined catfishes well represented, more so in fact than the equally abundant and only negatively if at all defended suckers. No fewer than 36 small catfishes were found in the stomach of a single belted kingfisher. The very spiny sticklebacks are eaten enough to show that their spines are no deterrent to the attacks of birds; no fewer than 150 of these little fishes have been taken from the stomach of a great blue heron. Advancing to the true prickly-scaled and spiny-finned fishes, we note that Centrarchids (sunfishes, bass, etc.) and perches are freely taken. High counts of sunfishes in stomachs are 12 in that of a least bittern, 14 in an anhinga, and 18 in a little green heron. Twenty yellow perch have been eaten at a meal by the least bittern and the great blue heron and no fewer than 25 darters by the little green heron. The Cottidae or sculpins often have a highly developed armature of spines about the head, but there is no evidence that it protects them from birds. Flatfishes (Pleuronectidae) represent almost the acme of protective coloration, especially of power to simulate the background, but they seem to be proportionally represented in our table. One double-crested cormorant had eaten 16 *Symphurus plagiusa*.

The unidentified fishes were distributed among approximately 165 species of birds to which a considerable number would have to be added to give the total number of fish-consuming species. A family

of fishes that almost everything "picks on," such as the minnows (Cyprinidae), was represented in the stomachs of 44 species of birds. Numbers up to 50 of these little fishes were found in stomachs of the belted kingfisher and the hooded merganser, and in the case of young of the common carp a high count of 106 was made from the stomach contents of a glossy ibis. Thirty-nine species of birds are known to prey upon the common killifishes and their allies; and numbers were taken from many stomachs, the maximum being 526 from a little blue heron.

Other enemies.—Fishes have no more destructive enemies than the predacious element among their own kind. Among the highly predatory marine forms may be mentioned the dogfishes and other sharks, swordfish, bluefish, squeateague, conger eel, and the angler, and among fresh-water fishes, the gars, sculpins, trout, amia, pikes, and bass. In a study of the fisheries of Buzzard's Bay, Mass., Field estimated that two species of sharks destroy more than 500,000 fishes annually in that body of water. Pearse found fishes to compose 12.3 per cent of the food of 32 species of their class in Wisconsin lakes. Forbes notes that the principal piscivorous fishes of Illinois, those which obtain three-fourths or more of their total subsistence from their fellow fin-bearers, are *Lota, Stizostedion, Esox, Micropterus, Ictalurus, Leptops,* and *Lepidosteus.* Six other species are listed as taking from 25 per cent to 65 per cent of fish food.

Predators devour fishes in all stages, and there are numerous special enemies of fish spawn; worst among these are other fishes such as the suckers, sculpins, minnows, sticklebacks, killifishes, top minnows, and trout.

Not many enemies of fishes are numbered among our batrachians and reptiles, those worthy of note including only the bullfrog, *Necturus* and *Cryptobranchus* of amphibians; the king, garter, and water snakes, copperhead, rattlesnake, and cottonmouth moccasin among snakes; and the painted terrapin, and snapping and soft-shelled turtles.

Some mammals are important enemies of fishes but the number is not large; we may mention the raccoon, mink, otter, seals, sea-lions, porpoises, and whales.

The young of fishes especially fall a prey to a variety of insects, as the larvae of aquatic beetles and of dragonflies, and to several kinds of water bugs and to hydras. Insects also, and crawfishes and leeches prey upon the eggs of fishes, and squids are said to be among the most destructive foes of adult fishes. Parasites of fishes abound and are recruited from the ranks of such diverse groups as bacteria, proto-

zoans, cestodes, trematodes, and crustaceans. Fishes are destroyed in large numbers sometimes by fungoid diseases; and enormous numbers of them perish by being stranded in pools, overflowed by high tides or freshets, which later dry up.

Discussion.—Forbes in his discussion of the "Food Relations of Fresh-water Fishes" notes that: "The soft-finned fishes were not very much more abundant, on the whole, in the stomachs of other species than were those with ctenoid scales, spiny fins, and other defensive structures,—an unexpected circumstance which I cannot at present explain" (p. 479). The natural comment upon this remark is that the fact detailed does not need to be explained, only accepted, theoretical bias being cast aside. He goes on to say: "Only the catfishes seem to have acquired defensive structures equal to their protection, the predatory apparatus of the carnivorous fishes having elsewhere outrun in development the protective equipment of the best-defended species" (p. 480). Examining the basis for this statement we find that Forbes examined the stomachs of about 900 adult or nearly adult fishes, and that he found catfishes in five of these stomachs; darters were identified only four times, whitefish only twice, and round suckers only three times, yet all of these are groups which equal or exceed catfishes in abundance. There is no reason therefore for saying their defenses are unusually efficient; from the table on p. 113 we see that birds take catfishes in due proportion.

Some kind of protectedness is claimed for practically every kind of fish, yet we see that all groups of them are devoured by natural enemies, and where data is available, predation seems to be very much in proportion to abundance. This principle is especially evident in depredations upon fishes if carried back through the life history of these animals; young fishes are more abundant than adults and they are greedily devoured by many piscivorous animals; while fish eggs, most abundant of all, are sought by a perfect swarm of predators. The grand principle of predation proportional to population is well supported by the known relations of fishes and their foes.

Amphibia (Salamanders, Toads, Frogs)

Protective adaptations.—All amphibians have skin glands that secrete a slime which some have thought to function partly as a defense. Toads in particular, frogs to a lesser extent, possess poison glands also, and "experiments have proved that toad poison injected into the system will kill any vertebrate, the dose being proportionate to the size of the animal." (Dickerson, Mary C., The frog book, p. 17,

1906.) Some amphibians have warning colors, but it is noticeable that the nearctic species having such coloration (certain *Ambystoma*) do not possess especially noxious secretions, while our toads are not at all warningly colored. The real defense of most amphibians lies in their habits, such as aquatic life, nocturnal activity, and lying in seclusion in burrows or under logs and rocks. Most of the species are very fecund also.

Bird enemies.—The extent to which the various families of Amphibia have been identified from the stomachs of nearctic birds is shown in the subjoined table.

Identifications of Amphibia

Group	Number of identifications	Percentage of identifications among those of all amphibians	Percentage of species of this group among North American amphibians [1]
Unidentified	132	13.2396	...
Urodela (further unidentified)	124	12.4372	...
Necturidae	4	.4012	1.4184
Typhlomolgidae	...	...	.0709
Amphiumidae	...	...	1.4184
Cryptobranchidae	...	...	.0709
Salamandridae	1	.1003	2.1276
Ambystomidae	16	1.6048	14.8932
Plethodontidae	8	.8024	31.9140
Sirenidae	...	...	1.4184
Anura (further unidentified)	40	4.0120	...
Discoglossidae	...	...	.0709
Scaphiopodidae	...	...	2.8368
Bufonidae	60	6.0180	9.9288
Hylidae	77	7.7231	14.1840
Leptodactylidae	...	...	2.8368
Ranidae	535	53.6605	12.0564
Brevicipitidae	...	...	2.8368

While the Ranidae are more abundant and accessible to birds than most of the other amphibians, even so they seem considerably overrepresented in the preceding tabulation, a circumstance that is explained in part by the fact that greater numbers proportionally of the stomachs of aquatic birds have been examined than of any other group.

[1] Computed from Stejneger, L., and Barbour, T., A check list of North American amphibians and reptiles, pp. 5-40, 1917.

Fifty-three species of birds are recorded as preying on Ranidae, of which the common crow is the most voracious (numbers as high as 24 and 29 individual frogs being counted in stomachs of this species), and has the largest number of records (197). Thirty-four frogs were found in the stomach of one little blue heron.

Among 14 species of toad eaters, the following are most important: common crow 16 records, red-tailed hawk 10, red-shouldered hawk 9, and broad-winged hawk 9. The most frequent consumer of salamanders also is the common crow with 83 records.

Total number of identifications of amphibians, 997; percentage of identifications among those of all vertebrates, 7.4844; percentage of species in this class among those of all nearctic vertebrates, 2.8313.

Other enemies.—Fishes occasionally eat the eggs of toads and frequently devour tadpoles of both toads and frogs, and the larger predacious fresh-water fishes are fond of frogs. The bullfrog especially preys upon other frogs and the gopher frog is a special enemy of toads. The Anura more or less frequently are cannibalistic upon the young of their kind, while larvae of salamanders regularly devour their brethren. Aquatic salamanders also eat the eggs and larvae of frogs. Snapping turtles, soft-shelled turtles, and alligators prey upon frogs, but it is particularly among snakes that the most deadly enemies of the Anura occur. The garter snakes and hog-nosed snake are especially fond of toads, while snakes in general eat frogs and also salamanders. In their account of the "Snakes of Okefinokee Swamp," Wright and Bishop report that: "With the larger snakes, the food most generally sought is Anura or Amphibia in general. It is *par excellence* the food of the aquatic snakes, and with these four or five species it is usually some species of *Rana*, though *Acris, Chorophilus* or *Hyla* may rarely appear as their prey. Equally important are frogs in the food of the larger land snakes, five species being addicted to them. With these the southern and oak toads (*Bufo*) are easily of first importance, with the tree frogs (*Hyla*) and the narrow-mouthed frog (*Engystoma*) occupying second and third places. In fact, these 10 snakes prefer the soft-bodied frogs and toads to any other food of the swamp (reptilian eggs not considered)." (Proc. Acad. Nat. Sci. Philadelphia, vol. 67, p. 147, Apr. 1915.)

Among mammals the skunk is known to be fond of toads, and coyotes, skunks, weasels, minks, otters, wildcats, and the brown rat feed upon frogs. No doubt most of these animals will take salamanders also when the opportunity occurs; the little spotted skunk and coyote are definitely known to do so, one stomach of the latter animal yielding 15 *Ambystoma*. The mongoose was found to feed

commonly on toads and frogs in three separate investigations of its food habits in Trinidad.

Leeches prey upon both eggs and young of amphibians and there are numerous insects which destroy tadpoles. Such are the giant water bugs, backswimmers, water scorpions, predacious diving beetles, and their larvae, and the nymphs of dragonflies. Finally, it should be mentioned that myriads of amphibian eggs and young perish because of the unwise choice by their parents of too temporary bodies of water for their egg-laying.

Discussion.—The relations of predators to amphibians throw an interesting light on the efficiency of protective adaptations in averting the attacks of foes. Clearly the Ranidae or frogs are more preyed upon than any other group, certainly much more so than the toads. The theorist on adaptations attributes this to the superior special defenses of toads, but with no doubt whatever the difference in amount of predation on these two groups is a direct reflection of their relative abundance.

If toads really were specially protected, if their so-called defenses actually saved them from a certain proportion of predatory attacks, should they not increase continually relative to the Ranidae? The fact that they do not is the best proof that could be asked that their "special defenses" do not actually function in nature. In short there is no reason to believe in the case of amphibians but that the attacks of predatory enemies bear a close relation to abundance and availability of the various orders and families. Where a certain group appears to have an advantage in escaping certain foes, to a degree, it invariably proves that it suffers extraordinarily from attacks of other enemies.

Reptilia (Turtles, Lizards, Snakes)

Protective adaptations.—Although turtles have the direct defenses of their shells, jaws and claws, several of the species have also a strong musky odor, and some exhibit warning colors. Numerous lizards have cryptic coloration; one of our species is poisonous and one has the faculty of changing its color considerably. Many lizards drop their tails easily, a device said to aid them in eluding enemies. The horned-toads besides their protective coloration have more or less prominent spines on the back of the head. Many snakes exhibit cryptic coloration and a number of them have offensively odorous secretions. Certain serpents practice intimidatory actions and a considerable number of our species are dangerously venomous.

Bird enemies.—Following is a tabulation of the records of Reptilia found in the stomachs of nearctic birds. The total number 695 seems proportional to the abundance of animals of this group in the United States.

Identifications of Reptilia

Group	Number of identifications	Percentage of identifications among those of all reptiles	Percentage of species of this group among North American reptiles [1]
Unidentified	21	3.0215	...
Crocodylidae	1	.1438	.6494
Lacertilia (further unidentified)	140	20.1432	...
Gekkonidae	...	...	.9741
Eublepharidae	...	...	.6494
Iguanidae	47	6.7624	22.0796
Anguidae	2	.2878	2.9223
Anniellidae	...	...	.6494
Helodermatidae	...	...	.0325
Xantusiidae	...	...	1.2988
Teiidae	5	.7194	4.8705
Scincidae	26	3.7409	4.8705
Ophidia (further unidentified)	250	35.9700	...
Bipedidae	...	...	.0325
Leposternidae	...	...	.0325
Leptotyphlopidae	...	...	.6494
Boidae	...	...	.9741
Colubridae	111	15.9707	35.0676
Elapidae	...	...	.6494
Crotalidae	1	.1438	5.8446
Chelonia (further unidentified)	84	12.0859	...
Kinosternidae	2	.2878	2.2729
Chelydridae	1	.1438	.6494
Testudinidae	3	.4316	9.7410
Cheloniidae	...	...	2.2729
Dermochelidae	...	...	.6494
Trionychidae	1	.1438	1.2988

In commenting on the foregoing table the obvious fact is recalled that our birds can hardly assume the rôle of predators upon turtles except in the case of rather small young of these animals. This limitation considered, 91 records seems fully as many as could be

[1] Computed from Stejneger, L., and Barbour, T., A check list of North American amphibians and reptiles, pp. 41-125, 1917.

expected. Forty-five species of birds participated in the lizard-eating, including some surprisingly diminutive ones such as the canyon and Carolina wrens and the white-eyed vireo. The road-runner, crows, jays, butcherbirds, and the Carolina wren took lizards most frequently. The chameleon, despite its powers of color change, was identified more often than any other species of lizard, namely, 24 times in the stomachs of 10 species of birds. One swallow-tailed kite had eaten seven specimens at a meal. Horned-toads and swifts, notwithstanding their defenses, which as it happens are diametrically opposed in character, were "among those present" in the stomachs.

In contrast to the comparatively wide distribution of the lizard determinations, those of snakes were shared by only 26 species of birds. Crows, hawks, and owls were the most important of these predators; and it is worth mentioning that the little Carolina wren again unexpectedly appears in the list. The superlatively cryptic green snake (*Cyclophis aestivus*) was eaten by red-shouldered and broad-winged hawks; the swift racers (*Bascanion*) by five species of hawks and the crow; the desperately bluffing hog-nosed snakes by the red-tailed and Swainson's hawks; the stinking garter and water snakes by several kinds of birds; and the redoubtable and warningly colored king snakes by the red-shouldered hawk. A great blue heron had swallowed a water snake (*Natrix fasciatus*) slightly over 25 inches long. The only venomous snake identified in the stomachs was *Crotalus confluentus* from a great horned owl but field observers credit another of our birds, the road-runner, with occasional depredations on rattlesnakes.

Total number of identifications of reptiles, 695; percentage of identifications among those of all vertebrates, 5.2173; percentage of species in this class among those of all nearctic vertebrates, 6.1847.

Other enemies.—While some of the larger predatory fresh-water fishes may occasionally devour a young turtle or small snake, actual records of the occurrence have not come to hand. The only one of our amphibians known to be a reptile eater is the bullfrog, which has been observed to eat snakes and newly-hatched turtles and alligators. Reptiles have numerous destructive enemies among their own ranks. Snapping turtles eat snakes; several kinds of snakes eat turtle eggs and a few the young; a few species of lizards prey upon other lizards, and a number of snakes devour both these animals and their eggs. Snakes are the worst enemies of snakes, such species as the racers, king snakes, ring-necked snakes, coral snakes, water moccasin, and copperhead being conspicuous in this respect. The king snakes are

immune to the poison of the venomous serpents and kill them whenever they run across them. Among mammals, skunks, raccoons, and bears dig up and devour the eggs of turtles; skunks, foxes, and wildcats eat snakes and lizards; the badger is known to feed upon tortoises and snakes, the coyotes on horned-toads and garter snakes, the opossum on horned-toads, and ground squirrels and grasshopper mice upon lizards.

Discussion.—The reptiles are not a very numerous group in our fauna and it would appear that they have natural enemies in due proportion. While some of the turtles are monarchs of the waters they inhabit when adult, yet their young must run the gauntlet of numerous enemies which cut the number down so that there are no indications whatever of an increase in the number of these species. So it is apparently with all the forms that when adult seem too large to have many enemies to fear; they are small and relatively helpless in the earlier stages of their life, and it is then that predators do great execution. In the class of reptiles, fratricide in almost every direction seems to be one of the most important elements of natural control. That such control is effectively exercised, the relatively stationary character of the reptile population sufficiently attests.

Aves (Birds)

Protective adaptations.—Much has been written about protective coloration in the bird world, including the nests, the eggs, the sitting bird upon the nest, and later the nestlings, the fledglings with their special plumages, and extending to the adults of hundreds of species, some of which (Anatidae) have a special protective dress, the eclipse plumage, during the season when the flight feathers are moulted. The ringed plovers of numerous species are said to have ruptive color patterns tending to break up the outline of the birds and render them inconspicuous. (The phylogenetic significance of this group character apparently is ignored.)

Crests of birds in some cases are said to be used to frighten their enemies, as are various sudden displays of contrastingly colored feathers elsewhere. Boldly marked birds of colors held to be warning in other classes of animals are numerous and the unusual often intense and striking coloration of the lining of the mouth of certain nestlings is held to be warning in effect. It has even been claimed that the color of some bird eggs advertises their low digestibility and that they are therefore avoided by all but ravenously hungry predators.

Bird enemies.—Birds, not content with preying upon animals of every class from protozoans to mammals, also draw upon their own

kind to the extent of a fourth (26.6 per cent numerically) of all their vertebrate food. The following table shows the distribution to families and two more inclusive groups of the determinations that have thus far been made of birds in the stomachs of nearctic birds.

Identifications of Aves

Group	Number of identifications	Percentage of identifications among those of all birds	Percentage of species in this group among nearctic birds [1]
Birds (further unidentified)	301	8.4669	...
Egg-shell	463	13.0327	...
Colymbidae	6	.1688	.7490
Gaviidae	...	...	.6242
Alcidae	3	.0844	2.7465
Stercorariidae	...	...	.4994
Laridae	3	.0844	5.2433
Rynchopidae	...	...	.1248
Diomedeidae	...	...	.6242
Procellariidae	...	...	3.8700
Phaethontidae	...	...	.3745
Sulidae	...	...	.7490
Anhingidae	...	...	.1248
Phalacrocoracidae	...	...	.7490
Pelecanidae	...	...	.2497
Fregatidae	...	...	.1248
Anatidae	26	.7314	7.2407
Phoenicopteridae	...	...	.1248
Plataleidae	...	...	.1248
Ibididae	...	...	.4994
Ciconiidae	...	...	.2497
Ardeidae	2	.0563	1.7478
Gruidae	...	...	.3745
Aramidae	...	...	.1248
Rallidae	19	.5345	1.9974
Phalaropodidae	3	.0844	.3745
Recurvirostridae	2	.0563	.2497
Scolopacidae	53	1.4908	5.2433
Charadriidae	5	.1406	1.7478
Aphrizidae	...	...	.4994
Haematopodidae	...	...	.4994
Jacanidae	...	...	.1248
Odontophoridae	23	.6470	.8739
Tetraonidae	26	.7314	1.7478
Phasianidae	265	7.4542	...
Meleagridae	...	...	.1248

[1] Computed from Check list of North American birds, prepared by a Committee of the American Ornithologists' Union, 3rd ed. (rev.), 430 pp., 1910.

Identifications of Aves—Continued

Group	Number of identifications	Percentage of identifications among those of all birds	Percentage of species in this group among nearctic birds
Cracidae	...	...	.1248
Columbidae	11	.3094	1.6229
Cathartidae	...	...	.3745
Buteonidae	...	...	2.8713
Falconidae	14	.3938	1.4980
Pandionidae	...	...	.1248
Aluconidae	...	...	.1248
Strigidae	15	.4219	2.3720
Psittacidae	...	...	.1248
Cuculidae	6	.1688	.8739
Trogonidae	...	...	.1248
Alcedinidae	...	...	.3745
Picidae	51	1.4346	2.9962
Caprimulgidae	1	.0281	.7490
Micropodidae	17	.4782	.4994
Trochilidae	...	...	2.2471
Cotingidae	...	...	.1248
Tyrannidae	10	.2813	3.8700
Alaudidae	12	.3375	.2497
Corvidae	20	.5626	2.8713
Sturnidae	2	.0563	.1248
Icteridae	111	3.1223	2.3720
Fringillidae	992	27.9040	11.6101
Tangaridae	11	.3094	.4994
Hirundinidae	76	2.1378	1.6229
Bombycillidae	34	.9564	.2497
Ptilogonatidae	...	...	.1248
Laniidae	1	.0281	.2497
Vireonidae	88	2.4754	1.4980
Coerebidae	...	...	.1248
Mniotiltidae	488	13.7270	6.8662
Motacillidae	7	.1969	.8739
Cinclidae	...	...	.1248
Mimidae	45	1.2658	1.3732
Troglodytidae	17	.4782	1.7478
Certhiidae	4	.1125	.1248
Sittidae	15	.4219	.4994
Paridae	38	1.0689	1.8726
Chamaeidae	1	.0281	.1248
Sylviidae	25	.7032	.7490
Turdidae	243	6.8353	1.8726

About one-eighth (13.02 per cent) of all the records are for bird eggs, and the number of species feeding upon eggs is so considerable

and represents so great a variety of birds (55 species) that the late Prof. F. E. L. Beal, taking these facts in connection with his field observations, was constrained to express the belief that scarcely a species of bird exists that upon good opportunity, can resist the temptation to eat another bird's eggs. Numbers of identifications such as 6 for the yellow-billed cuckoo, 10 for the brown towhee, 12 for the Baltimore oriole, 10 for the California towhee, and 11 for the bank swallow prove that egg or at least egg-shell eating is not confined to birds of the recognized predatory groups. Probably a number of the records are due to birds swallowing bits of their own egg-shells. On the other hand eggs may be punctured as by the house wren, or eaten without swallowing any of the shell, occurrences not likely to be registered in the evidence brought to light by stomach examination.

Of the records for predation upon the various families of birds, it may be said that the high number for Phasianidae represents domestic poultry almost entirely, and that of the other families, the two—sparrows and warblers—undoubtedly most numerous in individuals are those which bear the brunt of predatory attack. The rather high number of determinations of Turdidae reflect the abundance of the robin which contributed nearly 45 (43.6 per cent) of the total. The Icteridae, next in line, are birds of great abundance, which might be expected to rank still higher among the avian contributors to the subsistence of their predatory relatives. However, there is no evidence that they are at all immune to attack, as the great flocks of blackbirds wintering in our southern latitudes are constantly harried by predacious birds in variety and force.

The sparrows, most persecuted of all, because most available, represent almost the acme of protectively colored birds; the bob-whites (16 records), ruffed grouse (11), and their allies, also cited, as marvels of cryptic coloration are certainly eaten freely considering their relative numbers. It is of interest that birds of prey by no means spare each other, and it seems that a slight advantage in size is all that is needed to induce this strained predation; indeed there are records of intra-specific cannibalism. The pugnacious kingbird and other members of the family of tyrant flycatchers do not escape; the aerially expert swifts and swallows pay their due toll; and the green-coated vireos, best blended with foliage of any of our birds, are freely eaten.

Birds "warningly colored" that are represented in the dietary of other birds as illustrated by our tabulations include the bobolink (19 records), Baltimore oriole 4, orchard oriole 3, lark bunting 6,

cardinal 3, rose-breasted grosbeak 1, black-headed grosbeak 3, scarlet tanager 11, Blackburnian warbler 5, bay-breasted warbler 12, myrtle warbler 16, magnolia warbler 16, Canadian warbler 13, Wilson's warbler 10, hooded warbler 1, and the robin 106. These birds certainly have the colors and arrangement of colors said to be warning in the case of other animals, but brought home in the instances of these familiar and practically defenseless species, for none of which can any degree of inedibility be assumed, and in the light of the fact that all are eaten, some freely, some less so, in relation to their numbers, the theory of warning coloration becomes a wraith of the imagination so tenuous that one cannot understand why it ever received serious consideration.

Total number of identifications of birds, 3,555; percentage of identifications among those of all vertebrates, 26.6870; percentage of species in this class among those of all nearctic vertebrates, 16.0843.

Other enemies.—Fishes are not recorded as serious enemies of birds, but it is probable that sharks and some other highly predacious forms take some toll of birds that rest on the surface of the ocean. The goosefish is known to have eaten seven wild ducks at a meal and to have attacked such large birds as geese and loons. In fresh-water, bass have been observed to capture swallows. (Fins, feathers, and fur, p. 8, Dec. 1921.) The bullfrog is the only one of our amphibians known to eat birds, but records of its so doing are fairly numerous and some of the birds taken are surprisingly large (*e. g.* woodcock).

Among the snakes we find very serious enemies of birds, some of the expert climbing species especially, making birds, their eggs and young a considerable part of their diet. Most noteworthy in this respect are the pilot snake and black snake. Other bird-eaters are the garter, house, hog-nosed, king, and all of the Crotaline snakes.

The larger predacious mammals are very fond of birds and must be numbered among their worst enemies. Such are the opossum, wild cats, foxes, coyotes, raccoon, badger, and skunks. Smaller species as the weasels and mink are no less destructive and even the highly vegetarian squirrels never lose an opportunity to devour the eggs and young of birds. The red or pine squirrels are universally acknowledged to be among the most destructive foes of birds. The domestic cat, large numbers of which lead a more or less feral life, possibly is the most deadly single enemy of birds.

Recently much evidence has been gathered showing that the larvae of certain flesh flies (family Muscidae, sens. lat.) parasitize the nestlings of various birds, this activity resulting in the destruction of

numerous broods. Birds have other external as well as internal parasites also, the relation of which to mortality is not well known. An occasional bird falls a victim to mussels or other bivalves, to crayfishes, and to mantids and spiders.

Discussion.—"Warningly colored" nearctic birds, according to our tabulations, are eaten along with the others, the common ones frequently, the rarer ones to a lesser extent. Our most extensive family and the one most numerous in individuals, occupies the logical, if unenviable niche, as the most important contributor to the subsistence of predatory species. This family, the finches, includes many of the most "protectively colored" species. Fortunately there is other direct evidence of the way in which nearctic predators react to protective coloration. I refer to Dr. Raymond Pearl's paper on the "Relative Conspicuousness of Barred and Self-colored Fowls" (Amer. Nat., vol. 45, pp. 107-117, Feb., 1911). Natural enemies captured in one year 325 individuals out of a total of 3,443, a flock which contained both barred and solid-colored fowls. By all theories of protective coloration, the latter are the more conspicuous and should pay a higher toll to predatory enemies. Of the total number of birds 10.05 per cent were self-colored and of all the eliminated birds 10.77 per cent were self-colored. Thus these monochrome birds were taken almost exactly in proportion to their numbers in the whole flock. This is precisely the result that would be expected by those who have learned by study of the subject that availability is the one strongest factor in choice of food by predators. With availability as the controlling factor it follows that in the long run, and on the average, losses to predators will be very closely in proportion to the relative abundance of the group concerned.

Mammalia (Mammals)

Protective adaptations.—Many of the mammals are conceived to be very perfect exemplifications of protective or cryptic coloration. A few are credited with noxious qualities, accompanied in the case of the skunks only, in our fauna, by warning coloration. The short dense fur of moles and shrews is said to be a deterrent to predators and these animals are thought to be protected by a strong musky secretion also; shrews have even been credited with poisonous bites. However the most potent defenses of mammals in general against birds are their large size, and their teeth and claws.

Bird enemies.—Despite the size and direct means of defense of many species, mammals pay a heavy toll to bird predators. In our

complete tables, the group without doubt is over-represented, owing to the fact that stomachs of the hawks and owls have been kept examined practically up to date. However this fact probably does not materially affect the relative numbers of identifications for the different families, as shown in the following table for mammals alone.

Identifications of Mammalia

(Land mammals only)

Group	Number of identifications	Percentage of identifications among those of all mammals	Percentage of nearctic species in this group [1]
Further unidentified (in many cases carrion)	331	10.5046	...
Carrion (identified to species)	18	.5712	...
Didelphiidae	2	.0635	.2958
Talpidae	22	.6982	1.4790
Soricidae	274	8.6957	6.5076
Phyllostomidae	...	...	.2958
Vespertilionidae	19	.6030	3.5496
Molossidae	...	...	.1479
Ursidae	...	...	3.2538
Canidae	1	.0317	5.6202
Procyonidae	...	...	.5916
Mustelidae	1	.0317	8.5782
Felidae	1	.0317	...
Rodentia (further unidentified)	86	2.7293	...
Muridae	1,816	57.6326	24.1077
Geomyidae	31	.9838	7.9866
Heteromyidae	16	.5078	8.5782
Zapodidae	14	.4443	1.7748
Erithizontidae	...	...	.2958
Aplodontiidae	1	.0317	.7395
Sciuridae	173	5.4903	14.6421
Petauristidae	15	.4760	.7395
Castoridae	...	...	.2958
Ochotonidae	...	...	1.7748
Leporidae	330	10.4729	2.9580
Dasypodidae	...	...	.1479
Tayassuidae	...	...	.1479
Cervidae	...	...	3.9933
Antilocapridae	...	...	.1479
Bovidae	...	...	1.3311

[1] Compiled from Miller, Gerrit S., Jr., List of North American land mammals in the U. S. National Museum, 1911, U. S. Nat. Mus. Bull. 79, 455 pp., 1912.

Let us now take up some of the groups of interest in the order of their appearance in the tabulation. From the large number (274) of records for shrews it would appear certain that the alleged special defenses of these animals are no protection against birds. Thirteen species of shrews were identified in the stomachs; 27 species of birds are known to prey upon our common short-tailed shrew and 23 upon unidentified species of *Sorex*. Shrews are by no means gregarious, nevertheless five specimens of *Sorex personatus* were taken at a meal by a great gray owl. Considering their almost exclusively underground life, moles were captured fully as often as would be expected; the number of species of birds preying upon them is 12.

Bats, again on account of their nocturnal activity, are not greatly exposed to the attacks of birds. Six predators upon them are recorded in our tabulation with a total of 19 identifications. While the Mustelidae are provided with unusually strong musky scents, they are also rather above the size for many birds to attack. The single determination in our table, attributed to a crow, might perhaps be more correctly added to the records of carrion. Skunks, of this family, customarily cited as examples of animals having noxious qualities and warning coloration to advertise them certainly are too large for all except a very few species of our raptors to conquer. However there are a number of published and other records of the great horned owl preying upon skunks.

Muridae (mice and rats) are secretive, elusive animals with what would be called highly protective coloration, but this does not prevent their being the staple mammal food of birds. Meadow mice, perhaps our most ubiquitous rodents, are eaten by the largest number of species of birds, namely 44. Twenty-six species of birds are known to feed on the house mouse and 35 upon deer mice (*Peromyscus*). We have records of five species of birds preying upon our largest member of this family, the muskrat, and eight upon the smallest (*Reithrodontomys*).

Pocket gophers, like the moles, spend most of their lives underground and this fact limits the opportunities of birds for capturing them, yet there are 31 records for 11 species of birds; nocturnal and burrowing habits shield also the pocket mice and kangaroo-rats. Captures in these groups probably are in proportion to their reduced availability. Jumping mice (14 records), a more diurnal group, seem to be proportionately represented.

Erithizontidae (porcupines) are entirely beyond the size of prey practicable for birds, though possibly some of them are captured

when young. Mountain-beavers also are rather large and are inaccessible to any but owls, of which the great horned owl contributed our only record of their being eaten.

The large number of determinations of members of the squirrel family, cover, it must be recalled, such diverse groups as the spermophiles, prairiedogs, groundhogs, tree squirrels, and chipmunks. There are only two records of the groundhog, a very large rodent, one being captured by a goshawk and the other by a golden eagle. The number of identifications (15) of the chiefly nocturnal flying squirrels seems as large as could be expected. The cryptically colored rabbits are exceedingly common and live fully exposed to predacious birds, factors which go far toward accounting for the very large number of records of their being eaten. The remaining families in the list all consist of animals so large that only a few of the most formidable birds can prey upon them, and then only upon the young. There are observations of such occurrences, but it so happens that our records of stomach contents do not include any of them.

Total number of identifications of mammals, 3,151; percentage of identifications among those of all vertebrates, 23.6542; percentage of species in this class among those of all nearctic vertebrates, 13.5743.

Other enemies.—Fishes have few opportunities to capture mammals, but trout have been known to feed upon meadow mice and lemmings, and it is probable that other highly predacious fresh-water fishes occasionally get small mammals that venture near or in the water. The bullfrog is the only one of our amphibians known to eat mammals, an occasional mouse falling to its lot. The snapping turtles also get some mice and sometimes even capture animals as large as rabbits. Among snakes we find many habitual predators upon mice and other small mammals. Some results of studies of the food of snakes by the Pennsylvania Division of Zoology may be briefly cited: Pilot snake, mice 22 per cent of the diet, squirrels 11 per cent, weasels 4 per cent; black snake, mice 26 per cent, rabbits 4 per cent, other mammals 7 per cent; milk snake, mice 71 per cent, other mammals 11 per cent; copperhead, mice 41 per cent, shrews 4 per cent, other mammals 8 per cent. In the case of the timber rattlesnake, mice, rats, and rabbits composed nearly the whole diet. This is known to be true also of most of our venomous snakes.

The worst foes of mammals, however, are their own kind, and the diversity of their predatory habits may be indicated by brief references to their mammal prey. Opossums take limited numbers of small mammals, while raccoons and skunks prey more extensively upon

them, especially upon mice and ground squirrels. The bob cats or lynxes are fond of mice, ground squirrels, rabbits, and other rodents, occasionally prey upon small domestic stock, and are known to eat skunks and porcupines. The mountain-lion specializes upon deer, but eats a variety of wild mammals, including foxes, skunks, coons, porcupines, and bob cats. House cats take mice, rats, moles, shrews, and rabbits. Coyotes and wolves prey upon the young of deer and domestic stock, and upon prairie dogs, spermophiles, and other small rodents. On the bill-of-fare of our various species of foxes are shrews, mice, ground squirrels, pocket gophers, kangaroo-rats, and rabbits. Badgers also take all of these mammals and in addition, prairiedogs and mountain-beaver. The black-footed ferret is a special enemy of the prairiedog, and relishes rabbits also. Weasels are ferocious enemies of small mammals in general, and for their size, shrews are fiendish predators. They commonly overpower and devour other shrews and mice of their own or even of slightly greater bulk. The polar bear preys especially upon seals, and the killer whales also destroy these animals, as well as wearing down and devouring the largest of all mammals, whales.

Discussion.—Limitations due to relative sizes allowed for, we see the same phenomenon in the case of mammals as in those of other elements of bird food, namely that the more available (this usually meaning abundant) groups are preyed upon most extensively, while those which are less abundant or whose habitat is somewhat out of the domain of birds are not so often captured. We see that the burrowing moles and pocket gophers escape with moderate losses, but that the abundant mice, and the both common and relatively easier found rabbits suffer severely. It is evident also that the mammals outside the range of prey of birds have serious enemies, chiefly other mammals; and it is further evident that, taking all mammal enemies into consideration, they are most numerous in the case of so abundant and ubiquitous a group as the mice, and proportionally less numerous for other less abundant families.

DISCUSSION

Availability is a mighty factor in the choice of food by birds. Within the limits imposed by special habitats, bodily modifications, and the relative sizes of predator and prey, birds are prone to feed upon what is abundant and easily obtained. Not only is this very natural procedure the everyday order, but it is conspicuously exempli-

fied by the characteristic flocking[1] of birds to the scene of insect outbreaks or of other occurrences of unusual abundance of food.

Constant seeking of the available leads to a wide distribution of predatory attack because of seasonally or otherwise variable abundance or availability of many of the food organisms, further on account of the greater or lesser restriction of predators to specific habitats in each of which the range of food items is different, and because of the specialization of various predators in methods of seeking food.

That the predatory attacks of birds are amazingly distributed over the entire animal kingdom, preceding pages bear witness. If it be asked whether birds eat bats or moles, flyingfishes or hermit crabs, dragonflies or mole crickets, sea-urchins or bryozoans, the answer is ever in the affirmative. Given an animal group comprising only a small number of species we find that there are only a few records of birds preying upon it. Given one of large numbers of species we invariably find it is an important item of bird food. If the validity of depending upon the number of species as an index of frequency be questioned, no matter. The tendency for feeding to be distributed over the whole range of the available food organisms and in at least rough proportion to the known abundance of the various groups, is beyond dispute.

This principle, predation in proportion to population, stands out clearly in the tabulations of the animal food of nearctic birds here presented and discussed. Compared to it the effect of the so-called protective adaptations on character of food is negligible. If these adaptations controlled choice of bird food to a significant extent, discrimination would everywhere be evident; finding indiscriminancy, on the contrary, we must conclude that the ruling criterion in choice of food is availability.

Indiscriminancy of Predators other than Birds

Nearctic birds, as a group, are little influenced by the protective adaptations of available prey. Let us see what can be said of other classes of predators.

Odonata.—In a general article on "Predacious Insects and their Prey," Prof. E. B. Poulton says of a tabulation of dragonfly victims: "Short as it is, the list is extremely interesting, and raises the expectation that dragonflies will be found to prey rather largely upon

[1] American instances are summarized in the following paper: McAtee, W. L., The rôle of vertebrates in the control of insect pests, Smithsonian Rep. 1925, pp. 415-437, 7 pls., 1926.

specially defended groups of insects." (Trans. Ent. Soc. London 1906, p. 401, 1907.)

Agnatha, Plecoptera, et al.—In a report which deals with the food of stoneflies, mayflies, caddisflies, and Diptera in trout streams, Muttkowski and Smith state that "Aquatic insects in rapid streams are opportunists as regards food and eat whatever becomes available."[1]

Orthoptera.—Professor Poulton in the paper referred to says of the prey of these insects: "The proportion of specially protected forms was very high." (Op. cit., p. 408.)

Rhynchota.—Quoting from Poulton again, he says of bugs, "So far as it is possible to judge from the . . . . table it appears that Hemiptera will prove to be extremely dangerous foes to the specially protected groups." (Op. cit., p. 403.)

Diptera.—Writing of the food of the larvae of aquatic midges, A. L. Leathers says:[2] "The organisms found were so similar, both in number and variety, to those available in a given locality that there seemed to be little or no sorting in their method of feeding."

Professor Poulton remarks on robber flies that "A study of the table at once shows that the Asilidae are most indiscriminate in their attacks. The stings of the Aculeates, the distasteful qualities of Danainae and Acraeinae, and of the odoriferous Lagria, the hard chitinous covering of Coleoptera, the aggressive powers of Odonata, are alike insufficient protection against these active and voracious flies." (Trans. Ent. Soc. Lond. 1902, p. 336.)

Parasites.—"Certain species and groups of species [of insects] . . . . have, as far as we know, relatively few parasites in any region. . . . . This is sometimes considered to be due to the possession of protective devices of certain kinds, but the explanation is not satisfactory. Neither systems of colorations, nor nettling hairs, nor an armour of chitinised plates, nor rapidity of movement, nor the existence of toxic principles in the blood prevent insects from being decimated by parasites."[3]

Miscellaneous insects.—"Many groups of predacious insects also appear especially to attack the conspicuous, easily-captured prey provided by the groups with warning colours. This has been observed in

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[1] Muttkowski, R. A., and Smith, G. M., The food of trout stream insects in Yellowstone National Park, Roosevelt Wild Life Ann., vol. 2, no. 2, p. 261, Oct., 1929.

[2] Bull. U. S. Bur. Fisheries, vol. 38, Doc. no. 915, p. 3, 1922.

[3] Thompson, W. R., On natural control, Parasitology, vol. 21, no. 3, p. 279, Sept., 1929.

the case of the predacious asilid flies, Dragonflies, Hemiptera, Mantidae, and Locustidae." (Poulton, E. B., Essays on evolution, p. 318, 1908.)

Arachnida.—" Spiders are for the most part not very particular as to the insects they catch." (Bristowe, W. S., Proc. Zool. Soc. Lond., 1929, p. 643.)

" It is quite probable . . . . that certain species of spiders, together with Mantides and other predacious insects, will be found to be among the chief, perhaps the chief non-parasitic enemies of aposematic insects." (Poulton, E. B., Trans. Ent. Soc. Lond. 1902, p. 327.)

Pisces.—" In general, fish are opportunists as far as their food is concerned. They eat what animal food is available, regardless of the origin." [1]

The closeness with which the brook trout is guided by availability in its choice of food is indicated in the following table by Dr. P. R. Needham based on studies near Ithaca, N. Y.:

Comparison of Available Aquatic Fish Foods in Stream Bottoms and Aquatic Foods Consumed by Trout [1]

Order	Available aquatic foods		Consumed aquatic foods	
	Number	Per cent	Number	Per cent
Mayfly nymphs	2,316	36.90	356	30.12
Caddisfly larvae and pupae	1,335	21.27	528	44.67
Stonefly nymphs	921	14.67	41	3.47
Fly larvae and pupae	869	13.84	187	15.82
Beetle larvae	476	7.58	33	2.79
Crayfish and shrimps	235	3.74	14	1.18
Miscellaneous	125	1.99	23	1.94
Totals	6,277	99.98	1,182	99.99

[1] Quantitative studies of the fish food supply in selected areas, Suppl. 18th Ann. Rep. New York Conserv. Dep. 1928, p. 227, 1929.

Further testimony to the effect of availability on the food of fishes is contained in Muttkowski's study [2] of "The Fauna of Lake Mendota" in which he shows that insects form about 60 per cent by bulk

[1] Muttkowski, R. A., The ecology of trout streams in Yellowstone National Park, Roosevelt Wild Life Ann., vol. 2, no. 2, p. 229, Oct., 1929.

[2] Muttkowski, R. A., Trans. Wisconsin Acad. Sci. Arts and Letters, vol. 19, pp. 374-482, 1918.

of the macrofauna of the lake and about that proportion of the total diet of the fishes.

Some of the above remarks tending to emphasize feeding on protected forms are special pleading because their authors felt under the necessity of proving "protected" insects do have enemies. The various groups of predators thus referred to, however, prey upon other than the specially protected insects, just as birds do, and examined in that light, the comment "indiscriminate" would in most cases fit their food habits. An adaptation of Poulton's tabulation for robber flies illustrates the point.

Name of prey	Number of records	Percentage of records	Percentage of species in this group among the whole number of insect species known
Orthoptera	13	5.70	2.94
Rhynchota	12	5.26	8.58
Neuropteroidea	7	3.07	.71
Lepidoptera	32	14.03	15.61
Coleoptera	40	17.54	46.20
Diptera	57	25.00	11.44
Hymenoptera	67	29.34	17.17

This does not look very different from tabulations for birds, and clearly illustrates the same propensity demonstrated for that class, namely of preying largely upon the groups most numerous in species, and presumably therefore in individuals—in other words upon what is most available.

That availability does largely govern choice of food is the very thing that creates problems in wild life economics. When man invades the domain of wild life and in the various phases of his husbandry makes available large supplies of new foods, they are immediately attacked and up to a certain limit the enemies steadily increase in variety and abundance. It is needless to cite examples of this universal phenomenon from the vegetable kingdom. All may not realize, however, that it prevails also in the animal world. The temerity of the pioneer establishing an orchard in a clearing in the foothills where the crop is largely harvested by wild life, is paralleled by that of the sheep raiser who grazes his herds in mountain meadows where they are attacked at once by wolves, coyotes, wild cats, bears, and other predators. Man's taking the domestic fowl wherever he goes furnishes material for further demonstration of the supreme influence of availability. The chicken, a native of Asia should have no "natural

enemies" in other parts of the world, nevertheless in America for instance, a large number of predators, including hawks, owls, crows, jays, skunks, weasels, and foxes eagerly welcomed the new food.

More Theoretical Aspects of Indiscriminancy by Predators

The experience we have when we place inviting food supplies in abundance before the birds indicates what must happen in nature under similar circumstances. If we imagine a world of food available to predators we must realize that the elements composing it will be utilized very much in proportion to their abundance. This is only what would be expected if there is or ever was such a thing as the oft-mentioned "balance of nature." To preserve a balance, natural checks must be in proportion to population. If they were not apparently so, no balance would have been observed and the term balance of nature would never have been invented.

Distribution of predation in proportion to population also is what we should expect if the theory of adaptive radiation, or the occupation of every possible ecologic niche is correct. Given the world of prey to exploit it is inevitable that predation will extend in all possible directions. No source of food will be left untouched if by any possibility it can be drawn upon. Under so searching a campaign for food each inevitably will be utilized in proportion to its abundance.

That this principle actually is at work is well shown by a series[1] of studies by Harry B. Weiss which indicate that regardless of locality there is a more or less fixed set of ratios between types of food habits of insects. Thus from several widely separated areas the insect population groups into from 45 to 55 per cent of phytophagous species, from 15 to 27 per cent of saprophagous, from 14 to 19 per cent harpactophagous, from 10 to 12 per cent parasitic, and from 1 to 4 per cent of species of miscellaneous feeding habits.

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[1] Insect food habits and vegetation. Ohio Journ. Sci., vol. 24, no. 2, pp. 100-106, Mar., 1924.

Ratios between the food habits of insects. Ent. News., vol. 35, no. 10, pp. 362-364, Dec., 1924.

Notes on the ratios of insect food habits. Proc. Biol. Soc. Wash., vol. 38, pp. 1-4, Jan., 1925.

Insect food habit ratios on Quelpart Island. Psyche, vol. 32, no. 2, pp. 92-94, Apr., 1925.

The similarity of insect food habit types on the Atlantic and Western Arctic Coasts of America. Amer. Nat., vol. 60, no. 1, pp. 102-104, Jan.–Feb., 1926.

Weiss' table summarizing these interesting data is substantially quoted as follows:

	Number of species	Phytophagous. Per cent	Saprophagous. Per cent	Harpactophagous. Per cent	Parasitic. Per cent	Pollen feeders, misc. species. Per cent
Quelpart Island	577	55	15	19	10	1
Western Arctic Coast of N. A.	400	47	27	14	10	2
State of N. J.	10,500	49	19	16	12	4
State of Conn.	6,781	52	19	16	10	3

The similarity of the figures whether for the States of New Jersey or Connecticut, for the Pacific Coast of Arctic America, or from far flung Quelpart Island (Corea) shows that there is at work some principle controlling choice of food that overrides whatever effect the so-called protective adaptations may have.

It is almost certain that the constancy of the ratios is due to a tendency (one might well say a compulsion) toward distribution of predatory and parasitic attack. This distribution is one that lays every group under tribute, that takes toll from each so long as the tax is more easily collected there than elsewhere, but when that condition fails turns toward more easily available supplies.

Predation is thus kept proportional to population and practical indiscriminancy as to factors other than availability must result.

Indiscriminancy of Natural Checks other than Predators

It will not be questioned, we believe, that from the standpoint of protective adaptations such checks as parasites, bacterial and fungal diseases, heat, cold, and other climatic factors, are indiscriminate in action.

Relative Importance of Natural Checks

Years ago Chittenden writing of "Insects and the Weather"[1] stated: "It also appears to me what has been observed by Mr. Marlatt in the case of scale insects . . . . is true in general, viz., that favorable or unfavorable climatic conditions are of greater importance in

[1] Bull. 22, n. s., U. S. Div. Ent., pp. 51-64, 1900.

determining the abundance or scarcity of insects as a whole than are other natural checks such as parasitic and other enemies, or even fungous or bacterial diseases" (p. 63).

Recent studies have only crystallized long-held views to the effect that the grand overwhelming factors of insect control are climatic.[1] Thus Uvarov in discussing "Weather and Climate in their Relation to Insects,"[2] says:

> Apart from the seasonal rhythm in the appearance and activities of insects, there is a more or less strongly marked periodic fluctuation of a species from year to year. Only relatively few insect pests are equally numerous and injurious every year, while most of them are practically negligible, except in certain years, when mass outbreaks occur. It would be out of place to discuss here all the causes for these periodic fluctuations, but I would like to point out that recent researches in this direction tend to throw some doubt on the commonly accepted idea that the chief controlling factor is the parasites, since a number of cases have become known in which the factors normally keeping an insect species down are almost entirely of meteorological order. This has been admitted for the cotton boll weevil in America (Hunter and Pierce, 1912), for the corn-borer in Europe (Thompson and Parker, 1928), for the almond sawfly in Palestine (Bodenheimer, 1928), for the cotton seed bug in Egypt (Kirkpatrick, 1923), for plague fleas in India (Hirst, Rogers), for vine-moths in Europe (Stellwaag, 1925), and for some other notorious pests.

Again Bodenheimer in answering[3] the question "Welche Faktoren regulieren die Individuenzahl einer Insektenart in der Natur?" states that parasites, predators, and scarcity of food, are rarely or only secondarily of regulatory significance, but that climatic factors are the real controlling influences.

Accepting the great superiority of meteorological phenomena as regulative factors we may make some inquiry as to the relative importance of other controlling agencies. Diseases sometimes are dramatically destructive, but they rarely have a steady regulatory influence.

Among parasitic and predacious organisms it must be presumed, except for specific limiting factors, that their effectiveness as control agencies will be more or less in keeping with their total numbers. Thus we can deduce from a table such as that on page 9 that most

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[1] This statement has general validity, for insects are nine-tenths of the terrestrial animals above the size of nematodes, and probably a large proportion of the smaller animals, as well as part of the tenth of larger size are subject to similar checks.

[2] Uvarov, B. P., Conference of [British] Empire meteorologists, 1929, Agricultural Section, pp. 17-18.

[3] Bodenheimer, F. S., Biol. Zentralbl., vol. 48, pp. 714-739, 1928.

of the groups can play only minor rôles in the whole drama of predation, and that insects must occupy the center of the stage, regardless even of the superior individual size of the chordates.

To put the case in other language we may quote from David Sharp,[1] "Insects form by far the larger part of the land animals of the world; they outnumber in species all the other terrestrial animals together, while compared with the vertebrates their numbers are simply enormous" (p. 83).

"Insects derive their sustenance primarily from the vegetable kingdom. So great and rapid are the powers of assimilation of the Insect, so prodigious its capacity for multiplication, that the mammal would not be able to compete with it were it not that the great horde of six-legged creatures has divided itself into two great armies, one of which destroys the other" (p. 521).

SUMMARY

The hypotheses about protective and warning colors and mimicry are part of the Natural Selection group of theories. These coloration phenomena and other protective adaptations are supposed to have been developed and perpetuated by the selective value they had in shielding their possessors from attack by predators.

Preceding sections of this discussion call attention to the evidence that one group of predators after another is known either to prey habitually upon "specially protected" groups, or to be so largely guided in choice of food by availability as practically to ignore protective adaptations.

The former is admitted to be true of dragonflies, robber flies, mantids, predacious locustids and Hemiptera, parasitic insects, and of spiders, while the latter is stated to be characteristic of the aquatic immature forms of mayflies, stoneflies, caddisflies, and two-winged flies, and of fishes. Data cited throughout the main body of the present paper show a high degree of indiscriminancy also on the part of amphibians and reptiles.

In fact this general indiscriminancy on the part of predators is so evident that even ardent advocates of the selection theories have been impressed by it and one of them, G. A. K. Marshall, in a paper on the "Bionomics of South African Insects" says:[2]

If the view advocated by many, that birds cannot be reckoned among the principal enemies of butterflies in the imago state, be true, then I consider that we may practically abandon the whole theory of mimicry as at present applied to the Acraeinae and Danainae of South Africa at all events, for from what I

[1] Cambridge Nat. Hist., vol. 5, 1910.

[2] Trans. Ent. Soc. London, 1902, p. 356.

have observed of these insects, I am convinced that their warning coloration cannot have reference to either Mantises, Asilidae, or lizards, which are practically the only other enemies that can be taken into account. . . . . That they [birds] have been the chief, if not the only agents in the production of mimicry whether Batesian or Müllerian I have little doubt.

In other words selectionists practically rest their case on the reactions of birds to protective adaptations. The principal object of the present paper has been to show what those reactions are so far as nearctic birds are concerned, and there is no reason to suspect that the results are otherwise than typical for birds of the world.

The most outstanding feature of the records of the animal food of nearctic birds undoubtedly is the marvellous distribution of them through the phyla, orders, and subordinate systematic groups. Within size limits, animals of practically every kind accessible to birds are preyed upon, and as we consider the records for group after group a tendency for the number of captures to be in proportion to the abundance of the animals concerned is unmistakable. Availability undoubtedly is the chief factor involved in the choice of food, and predation therefore tends to be in proportion to population.

Considering bird predation alone this principle leads to a high degree of indiscriminancy in attack upon the whole kingdom of animal life. The combined attack of birds plus all other predators still more closely approaches complete indiscriminancy. In other words there is utilization of animals of practically every kind for food approximately in proportion to their numbers. This means that predation takes place much the same as if there were no such thing as protective adaptations. And this is only another way of saying that the phenomena classed by theorists as protective adaptations have little or no effectiveness.

Natural Selection theories assume discrimination in the choice of prey. The principle of proportional predation so obvious from the data contained in this paper vitiates those theories for it denotes indiscrimination, the very antithesis of selection.

Finally so far as the types of adaptations discussed in this paper are concerned the influence of such factors as disease and climatic factors, the last the most important of all in reducing animal populations, is completely indiscriminate.

The total mortality of animal groups is known normally to be in strict proportion to their numbers, *i. e.*, a pair of the new generation remains, to replace a pair of the old and it is apparent elimination of all but that pair is very largely due to agencies indiscriminate in their action. There would seem, therefore, to be no discriminative eliminating forces of sufficient strength to bear the very great burden put upon them by natural selection theories.

BIBLIOGRAPHY

A complete bibliography of the subject matter of this paper would fill volumes and nothing like it is attempted here. Articles on food habits cited are chiefly those from which notes supplemental to our tabulations were gleaned; few of foreign origin are included. The citations relating to enemies of various groups are illustrative only, not exhaustive, and some of exotic origin are used where helpful in indicating the wide distribution of predatory attack.

The bibliography is primarily one of predation and so far as possible entries are distributed according to the thing eaten. When the feeding habits are varied, entries are filed according to the group the diet of which is reported upon. Titles classifiable under either of these criteria are arranged according to the phyla or orders to correspond with divisions of the text. Those unclassifiable are grouped at the beginning of the bibliography as Miscellaneous.

MISCELLANEOUS

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Clark, A. H.

1925. Life in the ocean. Smithsonian Rep. 1923, pp. 369-394. Chiefly a discussion of food relations, many notes from which are used in this paper.

Ewing, H. E.

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Force, Edith R.

1925. Notes on reptiles and amphibians of Okmulgee County, Oklahoma. Copeia, no. 141, p. 26, Apr. Notes on examinations of the stomachs of 6 species.

Kjerskog-Agersborg, H. P.

1920. The utilization of echinoderms and of gasteropod mollusks. Amer. Nat., vol. 54, pp. 414-426, Sept.-Oct. Notes on these forms as food of fishes; short bibliography.

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McIntosh, W. C.

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Pratt, Henry S.
1923. Preliminary report on the parasitic worms of Oneida Lake, New York. Roosevelt Wild Life Bull., vol. 2, no. 1, pp. 55-71, Oct. Parasites of fishes, birds, reptiles, frogs, and mollusks.

Weed, C. M.
1884. The food relations of birds, frogs, and toads. Ent. Lab. Mich. Agr. Coll., pp. 20-29. Catbird 3 stomachs, robin 6, bluebird 2, crow blackbird 2, spotted frog 8, green frog 4, and toad 7.

Yonge, C. M.
1928. Feeding mechanisms in the invertebrates. Biol. Rev., vol. 3, no. 1, pp. 21-76, Jan. Notes on numerous food and enemy relationships. Full bibliography.

PROTOZOA

See entries under Miscellaneous, Blegvad, McIntosh, Yonge.

PORIFERA

See entries under Miscellaneous, Blegvad, McIntosh, Yonge.

COELENTERATA

See entries under Miscellaneous, Blegvad, McIntosh, Yonge.

PLATYHELMINTHES

Gamble, F. W.
1910. Platyhelminthes and Mesozoa, Cambridge Nat. Hist., vol. 2, pp. 1-120. "Turbellaria are carnivorous. . . . . Land Planarians feed on earthworms, molluscs and wood-lice; fresh-water Planarians on Oligochaet worms, water-snails, and water-beetles; marine forms devour Polychaet worms and molluscs. . . . . Certain Rhabdocoelida are mess-mates of Molluscs and Echinoderms, and a few others are truly parasitic—a mode of life adopted by all Trematodes save Temnocephala" (p. 4).

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1928. The interrelationships of insects and roundworms. Bull. Exp. Sta. Hawaiian Sugar Planters' Assoc., Ent. Ser. vol. 20, 68 pp., Jan. Some are primary parasites of orthoptera and bumble bees.

TROCHELMINTHES

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1910. Rotifera, Gastrotricha, and Kinorhyncha. Cambridge Nat. Hist., vol. 2, pp. 197-238. They devour algae, Infusoria, and other rotifers (p. 212).

MOLLUSCOIDA

OSBURN, RAYMOND C.

1921. Bryozoa as food for other animals. Science, n. s., vol. 53, pp. 451-453, May 13. Two species of ducks and 10 of fishes noted as predators upon bryozoa.

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CLARK, HUBERT LYMAN.

1920. Echinoderms in birds' stomachs. Science, n. s., vol. 51, pp. 594-595, June 11. Ducks and gulls feeding on holothurians and brittlestars.

DAWSON, J. W.

1867. The food of the common sea urchin. Amer. Nat., vol. 1, no. 3, pp. 124-125, May. Minute seaweeds mixed with diatoms and remains of small sponges.

ANNULATA

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1910. Chaetognatha. Cambridge Nat. Hist., vol. 2, pp. 186-194. "The food of the Chaetognatha consists of floating diatoms, Infusoria, small larvae, and . . . . Copepods, small Amphipods, larval fishes"; they are also cannibalistic (p. 190).

1910. Polychaeta. Cambridge Nat. Hist., vol. 2, pp. 245-344. "The Nereidiformia are mostly carnivorous, and feed on small Crustacea, Mollusca, sponges, and other animals; and Polynoids are even said to eat one another." The Terebellids and Cryptocephala feed on minute organisms strained from water; the deep sea forms feed on Radiolaria and Foraminifera (p. 296).

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MILLER, JOHN A.

1929. The leeches of Ohio. Distribution of the species together with what is known of their occurrence, food, and habitat. Ohio State Univ. Contr. vol. 2, Stone Labr., 38 pp. Feed on turtles, fishes, frogs, mammals, snails, worms, and insect larvae.

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1923. The control of blood-sucking leeches, with an account of the leeches of Palisades Interstate Park. Roosevelt Wild Life Bull., vol. 2, no. 1, pp. 9-53, 1 pl., 17 figs., Oct. Natural enemies of leeches include domestic and wild ducks, herons, kingfishers, crows, rats, minks, turtles, snakes, frogs, newts, fishes, crayfishes, dragonflies, and other predacious insects and leeches (pp. 29-30, 36).

CRUSTACEA

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Coleophora laricella. Birds sometimes consume 75 per cent but on the average about 25 per cent of the larvae; ants and pentatomids take a few; hymenopterous parasites of the pupal stage were of slight importance.

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1907. Hosts of insect egg-parasites in North and South America. Psyche, vol. 14, pp. 27-39, Apr. Coleoptera, 9 species, 10 egg parasites; Diptera, 1 species, 1 egg parasite; Hemiptera, 28 species, 43 egg parasites; Hymenoptera, 9 species, 11 egg parasites; Lepidoptera, 51 species, 68 egg parasites; Neuroptera, 1 species, 2 egg parasites; Orthoptera, 26 species, 47 egg parasites.

1911. Hosts of insect egg-parasites in North and South America, II. Psyche, vol. 18, no. 4, pp. 146-153, Aug. Coleoptera, 6 species, 6 parasites; Hemiptera, 10 species, 16 parasites; Hymenoptera, 2 species, 4 parasites; Lepidoptera, 15 species, 22 parasites;

Neuroptera, 1 species, 1 parasite; Odonata, 2 species, 5 parasites; Orthoptera, 4 species, 4 parasites; Platyptera, 1 species, 1 parasite.

McAtee, W. L.

1911. Economic ornithology in recent entomological publications. The Auk, vol. 28, no. 1, pp. 138-142, Jan. Clover root curculios (*Sitones hispidulus*) are recorded as being taken by 24 species of birds. Sorghum midge (*Contarina sorghicola*) apparently eaten by hummingbirds. New Mexico range caterpillar (*Hemileuca oliviae*)—preyed upon by robins. Crane flies (Tipulidae)—86 species of nearctic birds are known to feed upon tipulids and their eggs. Pentatomidae are eaten freely by a great variety of birds. Yellow bear caterpillar (*Diacrisia virginica*)—two species of birds, the black-billed cuckoo and the bob-white, are recorded as enemies. Mosquitos are preyed upon by more than 20 species of North American birds.

1911. Economic ornithology in recent entomological publications. The Auk, vol. 28, no. 2, pp. 282-287, Apr. Oakpruner (*Elaphidion villosum*) is recorded as preyed upon by four species of birds. Potato beetle (*Leptinotarsa decemlineata*)—21 species of birds are recorded as enemies of this pest. Hop flea beetles are eaten by killdeers and cliff swallows. Gipsy moths are recorded as being taken by 46 species of birds and brown-tail moths by 31. Alfalfa leaf weevil (*Phytonomus murinus*)—the English sparrow and the black-headed grosbeak are recorded as feeding on this weevil.

1911. Economic ornithology in recent entomological publications. The Auk, vol. 28, no. 4, pp. 505-509, Oct. Millipeds are recorded as being eaten by 83 species of birds, certain beetle larvae, toads, armadillos and skunks. Cutworms are eaten on sight by practically all birds that glean their food from the ground or from low vegetation. Flea beetles are eaten by various species of birds, in the case of *Crepidodera* by 26 species. Harlequin bug (*Murgantia histrionica*) is kept in check locally by the English sparrow. Cabbageworm (*Pontia rapae*) eaten by English sparrow. Codling moth—mortality during the winter as high as 90 per cent caused chiefly by birds, the beetle larvae, *Tenebrioides* sp., and diseases. Larch sawfly (*Nematus erichsoni*)—red-eyed vireos and cuckoos reported as feeding upon larvae of this insect.

1912. Economic ornithology in recent entomological publications. The Auk, vol. 29, no. 3, pp. 416-417, July. Billbug (*Sphenophorus callosus*) recorded as taken by nighthawks. False wireworms (*Eleodes*) preyed upon by 13 species of birds. Agricultural ant (*Pogonomyrmex barbatus molefaciens*)—eight species of birds recorded as foes. Alfalfa weevil recorded as taken by 31 species of birds, notable mention being made of the English sparrow.

1913. Economic ornithology in recent entomological publications. The Auk, vol. 30, no. 1, pp. 128-132, Jan. Boll weevils preyed upon by 53 species of birds. A rice weevil (*Lissorhoptrus simplex*)—the only natural enemies recorded are two species of birds. Plum curculio—seven species of birds recorded as enemies. Leafhoppers

known to be preyed upon by more than 120 kinds of birds, numerous species taking them in abundance. Nabidae, Lygaeidae, and spiders also mentioned as enemies.

1913. Economic ornithology in recent entomological publications. The Auk, vol. 30, no. 4, p. 602, Oct. Eight species of birds observed feeding on the larvae of the fruit tree leafroller (*Archips argyrospila*). May beetles and their larvae (*Lachnosterna*) preyed upon by 60 species of birds, the crow and crow blackbird probably being the most important enemies.

1914. Economic ornithology in recent entomological publications. The Auk, vol. 31, no. 3, pp. 421-422, July. Sugar-beet wireworm (*Limonius californicus*)—the California shrike an important enemy. *Crambus caliginosellus*—the quail and the kingbird noted feeding on this species. *Crambus laqueatellus*—the wood pewee observed taking large numbers. Rose aphid (*Macrosiphum rosae*)—house finch and white-crowned sparrow feeding on these aphids. Chinch bug—17 species of birds recorded as foes.

1915. Economic ornithology in recent entomological publications. The Auk, vol. 32, no. 2, pp. 253-254, Apr. Wireworms (*Elateridae*) are recorded as being taken by 90 species of birds. Grasshoppers—upward of 100 species of birds are known to feed upon these insects. Alfalfahopper (*Stictocephala festina*)—four species of birds recorded as enemies. Midges (*Chironomus*) are recorded as preyed upon by six species of birds.

1915. Bird enemies of forest insects. Amer. Forestry, vol. 21, no. 6, pp. 681-691, June. Bark beetles are preyed upon by more than 45 species of birds. Round-headed and flat-headed wood borers—the larvae of these insects are recorded to be eaten by all kinds of woodpeckers. Flat-headed apple tree borers are recorded as taken by the downy woodpecker. Carpenter ants—fully 50 species of birds are known to eat these insects. An average of nearly 30 per cent of the food of woodpeckers is recorded as being ants. No fewer than 46 kinds of birds are known to feed upon the gipsy moth in one or another of its stages. Thirty-one species of birds are recorded as enemies of the brown-tail moth. Orchard tent caterpillars are preyed upon by 43 species of birds, forest tent caterpillars by 32 and cankerworms by more than 50. Snow-white linden moth—the English sparrow is recorded as an important check on this insect. Plant lice are preyed upon by most small birds. Scale insects are known to be taken by more than 60 species of birds. Cicada—fishes and tortoises when opportunity presents, frogs, toads, lizards, squirrels, and a multitude of birds prey upon these insects.

1915. Economic ornithology in recent entomological publications. The Auk, vol. 32, no. 4, pp. 520-521, Oct. Katydids—birds recorded as important foes, special mention being made of chipping sparrows. *Calosoma sycophanta*—crows and hairy woodpeckers recorded as enemies of this beetle. Armyworm—more than 20 species of birds recorded as foes.

1915. Birds that feed upon pecan insects. Proc. Nat. Nut Growers' Assoc., pp. 40-41, Dec. 1. Pecan leaf caterpillar—birds known to feed upon pests of this genus (*Datana*) are robins, starlings, and two species of cuckoos. Fall webworm—four species of birds noted as enemies of this pest. Pecan weevil—64 kinds of birds are known to feed upon these beetles and congeners. White ants—of the 27 species of birds feeding on white ants, a flicker is recorded to have taken 1,100. Oakpruners are known to be preyed upon by four species of birds. *Cyllene*—five species of birds are recorded as enemies. Bark beetles are devoured by more than 45 kinds of birds. Plant lice and scale insects each are taken by 60 or more species of birds.

1916. Economic ornithology in recent entomological publications. The Auk, vol. 33, no. 2, pp. 216-217, Apr. Twelve-spotted cucumber beetle—27 species of birds recorded as enemies. Grasshoppers—six species of birds feeding upon them during an outbreak in New Mexico. Pine moth—the hairy woodpecker recorded as the most efficient natural force in restraining the Zimmerman pine moth.

1916. Economic ornithology in recent entomological publications. The Auk, vol. 33, no. 4, pp. 448-450, Oct. Armyworm (*Cirphis unipuncta*)—crows recorded as great destroyers of this pest; cowbirds and grackles also reported doing good work. Meadowlarks and robins observed eating the larvae. The armyworm has many natural enemies, among which are insects, reptiles, birds, and mammals. Skunks and toads undoubtedly eat thousands both of caterpillars and pupae. Clover leafhoppers are recorded taken by nine species of birds. Corn and cotton wireworm (*Horistonotus uhleri*)—birds are the only enemies of this pest recorded. Velvetbean caterpillar—the "ricebird" and the mockingbird eat many of these. California green lacewing flies (*Chrysopa californica*) are recorded as taken by two species of birds, the western wood pewee and the nighthawk.

1917. Bird enemies of a few insect pests. The Auk, vol. 34, no. 2, pp. 230-231, Apr. Grasshoppers are eaten by practically all birds, exceptions being the strictly vegetarian doves and pigeons. Fall armyworm—several common wild birds recorded as important enemies. Cabbageworm—the English sparrow, chipping sparrow and house wren recorded as enemies of this pest. Velvetbean caterpillars are preyed upon by the red-winged blackbird, the mockingbird, and the field sparrow.

1918. Economic ornithology in recent entomological publications. The Auk, vol. 35, no. 2, pp. 251-253. Apr. Potato aphid (*Macrosiphum solanifolii*)—chipping sparrows, quail, and English sparrows observed feeding on this pest. Sweet-potato leaf folder (*Pilocrocis tripunctata*) reported taken by the boat-tailed grackle. Cabbage looper (*Autographa brassicae*)—boat-tailed grackle observed feeding on adults and larvae. Pecan-leaf casebearer (*Acrobasis nebulella*) larvae taken by three species of birds. Fall webworm (*Hyphantria textor*)—red-eyed vireos recorded as destroying about 40 per cent of the larvae in Nova Scotia in 1916; other bird foes

noted are yellow-billed cuckoos and Baltimore orioles. Emperor moth (*Samia cecropia*)—cocoons destroyed by woodpeckers.

1918. Economic ornithology in recent entomological publications. The Auk, vol. 35, no. 4, pp. 493-495, Oct. Round-headed apple tree borer (*Saperda candida*)—entomologists record birds as enemies; the present note names five species as feeding upon the adults. Root-worms—37 species of birds recorded as enemies of *Diabrotica duodecimpunctata*, and 23 species as enemies of *Diabrotica soror*. Green plant-bugs (*Nezara* spp.) identified in stomachs of 31 kinds of birds, 100 individuals being found in the stomach of a Franklin's gull. Whitegrubs (*Lachnosterna* spp.) taken by 78 species of birds and 2 of toads.

1919. Economic ornithology in recent entomological publications. The Auk, vol. 36, no. 2, pp. 305-307, Apr. Woodpeckers noted as preying extensively upon larch bark beetles and borers. Grape root borer (*Memythrus polistiformis*)—the crested flycatcher observed feeding on the adults. Peach-tree borers (*Sanninoidea exitiosa* and *S. pictipes*)—two species of birds recorded as foes. Cankerworms preyed upon by 75 species of birds. Whitegrubs—several groups of birds named as enemies.

1920. Economic ornithology in recent entomological publications. The Auk, vol. 37, no. 2, pp. 322-325, Apr. False wireworms (*Eleodes*)—24 species of birds recorded as enemies. Lotus borer (*Pyrausta penitalis*)—red-winged blackbirds noted as foes of this pest. Round-headed apple tree borer (*Saperda candida*)—"Woodpeckers destroy great numbers of the borers by removing them from their burrows. . . . . In some cases from 50 to 75 per cent." Ten kinds of birds recorded as enemies. Flat-headed apple tree borer—12 species of birds recorded as preying upon the adults of *Chrysobothris*. Striped cucumber beetle (*Diabrotica vittata*)—17 species of birds noted as foes. Grainbugs (*Chlorochroa* spp.) recorded as taken by eight species of birds. Whitegrubs (*Phyllophaga*) preyed upon by 81 species of birds, the common crow being the most important enemy of both adults and larvae.

1921. Economic ornithology in recent entomological publications. The Auk, vol. 38, no. 2, pp. 302-304, Apr. Spotted apple tree borer (*Saperda cretata*)—"by far the most effective natural check to the increase of this borer seems to be the woodpeckers." Clover stem borer (*Languria mozardi*)—hymenopterous parasites, toads, and five kinds of birds recorded as enemies. Beet leaf beetle (*Monoxia puncticollis*)—enemies recorded are ladybird beetles, a stink bug, parasites, toads, and birds. Cabbage flea beetles (*Phyllotreta* spp.) 12 kinds of birds noted as foes. Grapevine flea beetle (*Altica chalybea*)—eight species of birds recorded as feeding upon this insect. Clover leaf weevil (*Hypera punctata*) preyed upon by 42 species of birds.

1922. Local suppression of agricultural pests by birds. Smithsonian Rep. 1920, pp. 411-438, pls. 1-3. In more than 70 cases birds apparently exterminated one or another of 32 insect pests locally.

1923. Economic ornithology in recent entomological publications. The Auk, vol. 40, no. 1, pp. 161-162, Jan. Pale western cutworm (*Porosagrotis orthogonia*)—records the western grasshopper sparrow, horned larks, and possibly other wild birds as enemies. Green June beetle (*Cotinis nitida*)—19 kinds of birds recorded as foes; southern corn root worm (*Diabrotica 12-punctata*) taken by 40 species of birds. Potato beetle (*Leptinotarsa decemlineata*)—fed upon by 25 species of birds.

1923. Economic ornithology in recent entomological publications. The Auk, vol. 40, no. 3, pp. 557-559, July. Corn ear worm (*Heliothis obsoleta*)—17 species of birds feed on this pest; more than 50 larvae were found in a single stomach of the boat-tailed grackle. Cloverleaf weevil (*Hypera punctata*)—records 43 species of birds preying upon this weevil. European corn borer (*Pyrausta nubilalis*)—five species of birds recorded preying upon larvae and three species observed catching the moths. Tussock moth (*Hemerocampa leucostigma*)—12 species of birds known to feed upon this insect in one stage or another. Lacewing flies (*Chrysopidae*)—17 species of birds recorded as predators, most of them taking the adults, but five known to eat the larvae.

1924. Economic ornithology in recent entomological publications. The Auk, vol. 41, no. 1, pp. 191-193, Jan. American silkworm (*Samia cecropia*)—Dr. John Tothill concludes from his observations in Nova Scotia that nearly three-fourths of the caterpillars are eaten by birds (orioles, robins, etc.), and about 85 per cent of the pupae are destroyed by woodpeckers. Apple leaf skeletonizer (*Hemerophila pariana*)—chipping sparrow observed feeding on the larvae. Mormon cricket (*Anabrus simplex*)—three species of birds mentioned as enemies, but birds said to be important factors in the control of these insects.

1924. Economic ornithology in recent entomological publications. The Auk, vol. 41, no. 4, pp. 629-632, Oct. False wireworms (*Eleodes* spp.)—13 kinds of birds recorded as enemies. Argus tortoise beetle (*Chelymorpha cassidea*)—identified in the stomachs of 14 species of birds, most often in those of the starling and kingbird. Codling moth (*Carpocapsa pomonella*)—woodpeckers recorded as important enemies, special mention being made of the red-bellied. Oak sapling borer (*Goes tessellatus*)—woodpeckers noted as destroying many larvae and pupae. Larch sawfly (*Lygaonematus erichsonii*)—four species of birds recorded as feeding upon the larvae, consuming about 10 per cent of them in New Brunswick. Larch casebearer (*Coleophora laricella*)—4 species of birds recorded as enemies. Spruce budworm (*Tortrix fumiferana*)—several species of birds and insect parasites noted as foes.

1926. Economic ornithology in recent entomological publications. The Auk, vol. 43, no. 3, pp. 396-398, July. Most common birds are enemies of the Japanese beetle (*Popillia japonica*). Green June beetle (*Cotinis nitida*)—observations show that starlings feed on the larvae and cardinals on the adults; in addition to these two birds, 22 other species are known to prey upon this pest. Striped cucumber beetle (*Diabrotica vittata*)—17 species of birds known

to feed on this beetle. The larvae or pupae of cattle grubs (*Hypoderma*) were found in stomachs of four species of birds; the robin also observed feeding on the larvae. Cankerworms (*Alsophila pometaria* and *Paleacrita vernata*)—76 species of birds listed as predators. Cabbageworm (*Pieris rapae*)—"Birds which are known to feed upon cabbage worms are the chipping sparrow, English sparrow, and house wren."

1926. Relation of birds to woodlots. Roosevelt Wild Life Bull., vol. 4, no. 1, 152 pp., 22 pls., Oct. Contains a section (pp. 101-136) on forest insect pests and their bird enemies discussed under the following heads: Plant lice (Aphididae), scale insects (Coccidae), cicadas (Cicadidae), walkingsticks (Phasmidae), flat-headed wood borers (Buprestidae), leaf chafers (Scarabaeidae), leaf beetles (Chrysomelidae), round-headed wood borers (Cerambycidae), bark beetles (Scolytidae), caterpillars (Lepidoptera), and sawflies, borer wasps, and ants (Hymenoptera).

1926. The role of vertebrates in the control of insect pests. Smithsonian Rep. 1925, pp. 415-437, 7 pls. General notes on amphibians, reptiles, and mammals as enemies of insects. Summarizes 109 cases of control and 88 of local suppression of insects by birds.

1928. Economic ornithology in recent entomological publications. The Auk, vol. 45, no. 4, pp. 526-528, Oct. Satin moth (*Stilpnotia salicis*)—five species of birds noted as enemies in Massachusetts. Western robins and bats reported as feeding on it in British Columbia. *Lygus elisus*—26 species of birds known to feed upon plant bugs of this genus. Cotton-stainers (*Dysdercus* spp.)—record of nine kinds of birds preying upon cotton stainers, and three species feeding upon other bugs of the same family. Fall armyworm (*Laphygma frugiperda*)—lists 13 species of birds as enemies, and notes that English sparrows have several times been observed to eradicate local infestations. Pale western cutworm (*Porosagrotis orthogonia*)—horned larks observed doing effective work against this pest.

MUTTKOWSKI, R. A., AND SMITH, G. M.

1929. The food of trout stream insects in Yellowstone National Park. Roosevelt Wild Life Ann., vol. 2, no. 2, pp. 241-263, Oct. Stoneflies, carnivorous forms prey chiefly on larvae and pupae of mayflies, caddisflies, midges; mayflies are chiefly scavengers; caddisflies: the carnivorous species are inclined to be cannibalistic, but they take also rotifers, midge larvae and pupae, and dead insects. Bibliography.

PATCH, E. M.

1906. White grubs and June beetles. [In circulars, finance, meteorology, and index.] Bull. 137, Maine Exp. Sta., pp. 286-287. Enemies noted: Skunks, moles, and ground squirrels in addition to a large number of birds prey on the grubs. Besides toads and frogs and possibly insectivorous snakes, a large number of birds feed on the adult beetles. Cecropia moth, p. 294: enemies noted are chickens, turkeys, and swine. The tent caterpillar, p. 296: natural enemies of this caterpillar include birds and parasitic insects; it is also susceptible to attack by bacterial and fungus diseases.

THOMPSON, W. R.

1929. On the relative value of parasites and predators in the biological control of insect pests. Bull. Ent. Research, vol. 19, pt. 4, pp. 343-350, Mar. Mentions parasitic habits for 3 families of Coleoptera, the Strepsiptera, 2 families of Neuroptera, 2 of Lepidoptera, 8 of Diptera, and 19 of Hymenoptera, and predatory habits in 3 families of Orthoptera, 9 of Neuroptera, the Odonata, some Corrodentia and Thysanoptera, in 8 families of Hemiptera, the Dermaptera, 19 families of Coleoptera, the Mecoptera, 2 families of Lepidoptera, 15 families of Diptera, and 6 of Hymenoptera. Thinks value of predators has been underestimated.

UVAROV, B. P.

1928. Insect nutrition and metabolism. A summary of the literature. Trans. Ent. Soc. London, pp. 255-343. Largely technical on metabolism, but some details of food are given. There is a section on carnivorous insects, pp. 269-270. Bibliography.

APTERA

MACNAMARA, CHARLES.

1924. The food of Collembola. Can. Ent., vol. 56, no. 5, pp. 99-105, May. Feed on sap, pollen, diatoms, algae, carrion, and Collembola.

ODONATA

BURNHAM, EDWARD J.

1899. Preliminary catalogue of the Anisoptera in the vicinity of Manchester, N. H. Proc. Manchester Inst. Arts and Sci., vol. 1, pp. 32-34. Certain birds appear to feed exclusively upon these insects while they last. The dragonflies mentioned are *Macromia illinoensis* and *Tetragoneuria semiaquea.*

CALVERT, PHILIP P.

1893. Catalogue of the Odonata (dragonflies) of the vicinity of Philadelphia, with an introduction to the study of this group of insects. Trans. Amer. Ent. Soc., vol. 20, no. 3, pp. 205-206, July-Sept. Notes on numerous bird enemies of dragonflies.

LAMBORN, ROBT. H.

1890. Dragonflies vs. mosquitoes, 202 pp., 9 pls. Nymphs feed on mosquito larvae, upon each other, upon water beetles, bugs, and small fishes. Not worth encouraging as mosquito enemies; fish and waterfowl also are foes of mosquitoes.

LUCAS, W. J.

1908. Foe of dragonfly nymphs. Entomologist, vol. 41, p. 16. *Notonecta glauca.*

LYON, MARY B.

1915. The ecology of the dragonfly nymphs of Cascadilla Creek (Odon.). Ent. News, vol. 26, no. 1, pp. 1-15, Jan. Notes on stomach contents of 36 specimens, midge larvae the most prominent item of food, but mayflies, *Corixids,* dytiscids, amphipods, cladocera, ostracods, hydrachnids, and snails were eaten.

MOORE, J. PERCY.

1900. Kingbirds eating dragonflies. Ent. News, vol. 11, p. 340. *Epiaeschna heros;* habitually captures them.

NEEDHAM, JAMES G.

1898. Birds vs. dragonflies. Osprey, vol. 2, nos. 6-7, pp. 85-86, Feb.-Mar. Review of notes by Rene Martin on European hobby and swift as enemies; *Merops persicus* lines its nest with their wings; when teneral, chipmunks, frogs, toads, snakes, ants, and birds eat them. Various birds eat nymphs.

1918. [Food of Odonata.] In Fresh-water biology, by Ward and Whipple, p. 890. Diptera and other dragonflies.

NEEDHAM, JAS. G., AND HEYWOOD, HORTENSE B.

1929. A handbook of the dragonflies of North America, 378 pp., illus. Food, flies, mosquitoes, honey bees; enemies, birds, frogs, fishes, water snakes, spiders, other dragonflies; large numbers sometimes destroyed by storms.

SHARP, DAVID.

1910. [Enemies of Odonata.] Cambridge Nat. Hist., vol. 5, pp. 424-425. Hawks, bee-eaters, other birds, fishes, snakes, newts, aquatic Coleoptera, Hemiptera, and other Odonata.

WALKER, E. M.

1924. The Odonata of the Thunder Bay District, Ontario. Can. Ent., vol. 56, no. 7, pp. 170-176, July; no. 8, pp. 182-189, Aug. Dragonflies found in stomachs of sucker, whitefish, sturgeon, and golden-eye ducks; a dragonfly nymph observed eating an adult of same species.

WILSON, CHARLES BRANCH.

1920. Dragonflies and damselflies in relation to pondfish culture, with a list of those found near Fairport, Iowa. Bull. 36, U. S. Bur. Fisheries, pp. 182-264, pls. 67-69, figs. 1-63, Aug. Notes on contents of alimentary canals of 250 nymphal and many adult Odonata; citation of previous studies; full bibliography. Odonate nymphs, diving beetles, water-scorpions, other aquatic Hemiptera, Hydra, nematodes, fungi, birds, fishes, reptiles and amphibians prey on nymphs; Diptera and Hymenoptera parasitize the eggs; and birds, other dragonflies, ants, spiders, robber flies, frogs, and fishes prey upon the adults, which also have both external and internal parasites.

AGNATHA

See various entries under Pisces; also Muttkowski and Smith under Miscellaneous Insects.

NEEDHAM, JAMES G.

1920. Burrowing mayflies of our larger lakes and streams. Bull. U. S. Bur. Fisheries, vol. 36 (1917-1918), pp. 269-292, pls. 70-92. Mayflies of prime importance as food of fishes; quotations from Forbes, Wagner, and Pearse, as to their value (pp. 270-271).

PLECOPTERA

See various entries under Pisces; also Muttkowski and Smith under Miscellaneous Insects.

ISOPTERA

[Hagen, H.]

1881. [Letter on birds vs. termites.] Proc. Boston Soc. Nat. Hist., vol. 20, 1878-1880, p. 118. Record of 15 species of birds following an emigration of white ants, robins, bluebirds, and sparrows being mentioned.

[Longstaff, G. B.]

1918. A flight of winged termites at Barrackpore. Trans. Ent. Soc. London, 1918, pp. lxiv-lxvi. Lizards, bullfrogs, rats, cats, dogs, jackals, mongoose, crows, Indian mynah, bats and cockroaches observed eating white ants.

Snyder, T. E.

1920. [Nearctic Termites.] Notes on biology and geographic distribution. U. S. Nat. Mus. Bull. 108, pp. 87-211. Termite checks include parasitic fungi, protozoans, nematodes, mites, and predacious ants, robber flies, beetle larvae, crickets, spiders, centipeds, lizards, and domestic and wild birds (pp. 116-118).

1924. New termites and hitherto unknown castes from the Canal Zone, Panama. Journ. Agr. Research, vol. 29, no. 4, p. 182, Aug. 15. Ants and anteaters as foes.

DERMAPTERA

Brindley, H. H.

1920. Notes on certain parasites, food, and capture by birds of the common earwig (*Forficula auricularia*). Proc. Cambridge Phil. Soc., vol. 19, (1916-1919) pp. 167-177. Fourteen species of British birds known to eat earwigs; also domestic fowls.

Morgan, W. P.

1924. Notes on the function of the forceps in earwigs. Proc. Indiana Acad. Sci., vol. 33, (1923), pp. 303-306, 7 figs. Earwigs are predatory and cannibalistic, use forceps in capturing and holding prey.

Sharp, David.

1910. Forficulidae—earwigs. Cambridge Nat. Hist., vol. 5, pp. 202-216. Eat larvae, snails, flowers, vegetables.

CHELEUTOPTERA

Badenoch, L. N.

1899. [Enemies of Phasmidae.] True tales of the insects, p. 48. Birds, lizards, mantids, bugs; eggs parasitized.

Sharp, David.

1910. Phasmidae—stick and leaf insects. Cambridge Nat. Hist., vol. 5, pp. 260-278. Vegetarian, but sometimes cannibalistic. Enemies include birds, Hemiptera, ichneumon flies.

SALTATORIA

Aughey, Samuel.

1878. Notes on the nature of the food of the birds of Nebraska. 1st Ann. Rep. U. S. Ent. Comm. (1877), Appendix II, pp. [13-62.] Records migratory locusts from the stomachs of 172 species of birds and field observations on 33 other species eating them.

BADENOCH, L. N.

1899. [Enemies of locusts.] True tales of the insects, pp. 127-128. Especially "locust birds"; but bears, skunks, squirrels, mice, frogs, and lizards are mentioned.

BRUNER, LAWRENCE.

1902. Grasshopper notes for 1901. Bull. 38, Div. Ent., pp. 39-49. Chickens, turkeys, blackbirds, sage grouse and sharp-tail grouse mentioned as natural enemies.

1905. Grasshopper conditions in Nebraska, Northeastern Colorado, Wyoming, Montana, and Western Kansas during the summer of 1904. Bull. 54, U. S. Bur. Ent., pp. 60-64. "Magnificent examples" of the usefulness of gulls as grasshopper destroyers; turkeys used to combat the insects.

BRYANT, H. C.

1912. Birds in relation to a grasshopper outbreak in California. Univ. California Publ. in Zool., vol. 11, no. 1, pp. 1-20, Nov. Los Banos; 15 species of land birds were found to eat the insects. Tame ducks also important. The native birds were calculated to be destroying daily 120,445 grasshoppers per square mile.

BURRILL, A. C.

1920. Meadowlarks control cricket pest. California Fish and Game, vol. 6, no. 1, p. 38, Jan. Meadowlarks recorded as important enemies of the coulee cricket.

CRIDDLE, NORMAN.

1920. Birds in relation to insect control. Can. Field-Nat., vol. 34, no. 8, pp. 152-153, Nov. Crows, gulls, black terns, blackbirds, and grouse recorded as destroying large numbers of grasshoppers.

1922. [Enemies of grasshoppers.] Can. Field-Nat., vol. 36, no. 4, pp. 66-68, Apr. Diptera, Hymenoptera, Coleoptera, birds, mammals (skunks, badgers, weasels, pocket mice, shrews, gophers), snakes, toads, and frogs.

GILLETTE, C. P.

1905. The western cricket. Colorado Agr. Exp. Sta., Bull. 101, 16 pp., Apr. *Anabrus simplex*. Bears and coyotes feed upon this pest but birds destroy them in greatest numbers; hawks, sage grouse and blackbirds noted (p. 7).

GRASSÉ, P.

1924. Les ennemis des Acridiens ravageurs francais. Rev. Zool. Agr. Appl., Bull. Soc. Zool. Agr., vol. 23, no. 1, pp. 1-14, pl. 1, figs. 1-4, Jan. Mammals, birds, reptiles, spiders, mites, wasps, beetles, flies, nematodes and Protozoa.

LUGGER, OTTO.

1889. Notes on the Rocky Mountain locust in Otter Tail County, Minnesota, in 1888. 5th Bienn. Rep. Dep. Agr. Minn., Suppl. 1, pp. 305-343, 22 figs. Nematodes, mites, tachina flies, bee flies, blister beetles, ground beetles, soldier beetles, robber flies, digger wasps, dragonflies, birds, skunks, shrews, toads, snakes, and turtles mentioned as enemies.

McAtee, W. L.

1913. Economic ornithology in California. The Auk, vol. 30, no. 1, pp. 132-136, Jan. H. C. Bryant records 22 species of water and shore birds and 40 species of land birds as enemies of grasshoppers.

1917. Economic ornithology in recent entomological publications. The Auk, vol. 34, no. 4, pp. 497-498, Oct. Grasshoppers are found on the bill-of-fare of practically all wild birds; freely eaten also by chickens and turkeys.

Merrill, D. E.

1916. [Enemies of grasshoppers.] Bull. 102, New Mexico Agr. Exp. Sta., pp. 15-16, Apr. Birds; fields near breeding grounds of the blackbirds are free from grasshopper damage; poultry; skunks; mites; parasitic flies; ground beetles; blister beetles; bee flies.

Morse, Albert P.

1920. [Enemies of Orthoptera.] Proc. Boston Soc. Nat. Hist., vol. 35, p. 271. Frogs, toads, salamanders, snakes, lizards, birds, mice, moles, shrews, skunk, and fox.

Sanderson, E. Dwight.

1906. The differential locust. Bull. 57, U. S. Bur. Ent., pp. 19-26, figs. 9-11. *Melanoplus differentialis*. Blackbirds and bobolinks suppressing an infestation; a conopid fly parasite also mentioned.

1906. Report on miscellaneous cotton insects in Texas. Bull. 57, U. S. Bur. Ent., p. 22. Blackbirds and bobolinks checking an outbreak of *Melanoplus differentialis*.

Sharp, David.

1910. [Enemies of Orthoptera.] Cambridge Nat. Hist., vol. 5, p. 291. Cantharidae, Bombyliidae, and mites destroy eggs; birds and mammals eat adults.

Smith, Harrison E.

1915. The grasshopper outbreak in New Mexico during the summer of 1913. Bull. 293, U. S. Dep. Agr., 12 pp. 2 figs. Six species of birds, several species of lizards, prairiedogs, a sarcophagid parasite, and a wasp observed doing notable execution.

Treherne, R. C. and Buckell, E. R.

1924. The grasshoppers of British Columbia. Bull. 39, Dominion of Canada Dep. Agr., pp. 29-35, Oct. Enemies include: nematodes, Diptera, Hymenoptera, Coleoptera, fungi and bacteria.

U. S. Entomological Commission.

1878. First annual report . . . . for the year 1877 relating to the Rocky Mountain locust, etc., pp. 477+[294], 111 figs., 5 pls. Invertebrate enemies (pp. 284-334) include larvae of anthomyiid and sarcophagid flies, ground beetles, blister beetles, click beetles, soldier beetles, robber flies, and mites all attacking the eggs; and the following preying upon the locusts after birth: mites, ground beetles, tiger beetles, robber flies, wasps, tachinid and sarcophagid flies, ichneumonids and nematodes. The vertebrate enemies (pp. 334-350) include birds, hogs, skunks, prairie squirrels, mice, and toads. Appendix II [pp. 13-62], is devoted to an account of the food of birds especially in relation to the locust.

PALEOPTERA

SHARP, DAVID.

1910. Blattidae—cockroaches. Cambridge Nat. Hist., vol. 5, pp. 220-241. Food chiefly dead animal matter, but a great variety of refuse also taken. Enemies include birds, rats, scorpions, spiders, and wasps (Ampulicides).

DICTYOPTERA

SHARP, DAVID.

1910. Mantidae—soothsayers or praying insects. Cambridge Nat. Hist., vol. 5, pp. 242-259. Voracious, eating insects of all kinds including their own, and even small birds.

CORRODENTIA

Food animal and vegetable refuse, and fungi.

MALLOPHAGA

Externally parasitic on birds and mammals.

SIPHONAPTERA

External parasites on birds and mammals.

RHYNCHOTA

CLARK, L. B.

1928. Seasonal distribution and life history of *Notonecta undulata* in the Winnipeg Region, Canada. Ecology, vol. 9, no. 4, pp. 383-403, pl. 20, 1 fig., Oct. Summary of literature as to food and enemies, pp. 395-399. Food: eggs of giant water bug, water-boatman, eggs and nymphs of dragonflies, ostracods, copepods, newly hatched fishes. Enemies: giant water bug, water-scorpion, waterstrider, dragonfly nymphs, fishes, and birds.

CURRAN, C. HOWARD.

1920. Observations on the more common aphidophagous syrphid flies (Dipt.). Can. Ent., vol. 52, no. 3, pp. 53-55, Mar. Larvae of five species consumed on the average from 15 to 47 plant lice daily.

DISTANT, W. L.

1892. A monograph of the Oriental Cicadidae, pp. vii-viii. "The Cicadidae appear to be one of the most non-protected families of insects and are the victims of most predacious creatures." Mentions birds, mantids, spiders, dragonflies, wasps, hymenopterous parasites and fungi.

FLUKE, C. L.

1929. The known predacious and parasitic enemies of the pea aphid in North America. Research Bull. 93, Wisconsin Agr. Exp. Sta., 47 pp., 3 pls., 32 figs. Mites, spiders, crickets, lacewing flies, Hemiptera, Coleoptera, Diptera, Hymenoptera, and birds. Lacewings, ladybirds, and Syrphidae appear to be most important.

FULLAWAY, DAVID T.

1920. Natural control of scale insects in Hawaii. Proc. Hawaiian Ent. Soc. (1919), vol. 4, no. 2, pp. 237-246, June. Forty-four species of scale insects, 87 parasites, 20 predators; varying up to 3 predators and 7 parasites to a species.

GARMAN, H.

1898. The chinch bug. Bull. 74, Kentucky Agr. Exp. Sta., pp. 45-70, figs. 1-10, May. Coccinellids, toads, quail, and meadowlarks prey upon it (p. 51); great fluctuations in abundance caused by disease.

GIBSON, EDMUND H.

1916. The clover leafhopper and its control in the central States. Farmers' Bull. 737, U. S. Dep. Agr., 8 pp., 5 figs., June. *Agallia sanguinolenta.* More than 100 species of birds, chickens, turkeys, and guinea fowl prey upon leafhoppers (p. 5).

HANFT, H.

1916. Beiträge zur Kenntniss der Cicadinenfeinde. Zeitschr. wiss. Insektenbiol., vol. 12, pp. 200-204, 217-223, 274-279, figs. Stresiptera, Dryinidae, Serphoidea, Pipunculidae, Neuroptera, Nematoda, mites, fungi. Bibliography.

HUNGERFORD, H. B.

1919. The biology and ecology of aquatic and semi-aquatic Hemiptera. Kansas Univ. Bull., vol. 11, 265 pp., 30 pls. Gelastocoridae—grasshoppers, lace bugs, beetle larvae, capsids. Ochteridae—tabanid larvae. Saldidae—drowned flies, etc. Hydrometra—Ostracoda, culicid larvae and pupae. *Mesovelia*—springtail, crambus, chalcid, Hydrometra, Ostracoda. *Gerris remigis*—midges, notonectid nymphs; jassids, etc., falling in water, snails. *Rheumatobates*—Ostracoda and fallen insects. *Microvelia*—Ostracoda and fallen insects, waterfleas. *Belostoma*—fish, snails. *Lethocerus*—frog, fish. *Nepa*—mayfly nymphs, Gyrinidae, Daphnia, Cyclops, fish eggs, fish, tadpoles. *Ranatra*—ostracod, fish, mayfly nymphs. *Plea*—Ostracoda and other small Crustacea. *Notonecta*—cannibalistic, Ostracoda and other small Crustacea, corixids. *Buenoa*—Entomostraca, corixids. Corixid nymphs cannibalistic.

JENSEN-HAARUP, A. C.

1924. Wasps preying on cicadas, Ent. Meddel, vol. 14, pp. 323-324. Also birds, spiders, mantids, and dragonflies noted as their enemies.

JOHNSON, ROSWELL H.

1907. Economic notes on aphids and coccinellids. Ent. News, vol. 18, no. 5, pp. 171-174, May. Coccinellids, syrphids, spiders, and fungi as aphid destroyers.

KIRKALDY, G. W.

1907. [Enemies of Aleyrodidae.] Bull. 2, Board Agr. and For. Terr. Hawaii, pp. 80-84. Three species of flies, 4 of beetles, 1 of hemiptera, 22 of hymenoptera, 1 neuropteron, 1 thysanopteron, 1 mite, and 2 fungi.

LORANDO, N. T.

1929. A biological method for destroying bedbugs. Sci. Monthly, pp. 265-268, Sept. Spiders, reduviid bugs, cockroaches, and ants as enemies.

LUGGER, OTTO.

1895. [Enemies of the chinch bug.] Bull. 37, Minnesota Agr. Exp. Sta., pp. 178-179. Birds, reptiles, frogs, toads; some specified.

MACANDREWS, A. H.

1923. Some notes on the natural control of the pine bark aphid (*Chermes pinicorticis* Fitch) in New Brunswick, 1922. Proc. Acadian Ent. Soc., vol. 8, 1922, pp. 52-56. A coccinellid exerted from 75 to 90 per cent of the natural control, and a syrphid fly and ant-lion the remainder.

MARLATT, C. L.

1907. The periodical cicada. Bull. 71, U. S. Bur. Ent., 181 pp., 6 pls., 68 figs. Natural enemies include dipterous, hymenopterous, and mite egg parasites, tachinid parasites of the adult, wasps, birds, squirrels, fishes; in some cases birds ate the insects as fast as they emerged.

McATEE, W. L.

1907. Birds that eat scale insects. U. S. Dep. Agr. Yearbook, 1906, pp. 189-198. Fifty-seven species of birds are recorded as feeding upon scale insects.

1913. Relation of birds to [an outbreak of] grain aphides. U. S. Dep. Agr., Yearbook 1912, pp. 397-404. Spring migrant birds on about 100 acres of grainfields in North Carolina destroyed about 1,000,000 grain aphids daily.

1918. Bird enemies of tree hoppers (Membracidae). The Auk, vol. 35, no. 3, pp. 373-374, July. Treehoppers identified in the stomachs of more than 120 species of birds, as many as 26 individuals being found in a single stomach.

McGREGOR, E. A.

1927. *Lygus elisus:* a pest of the cotton regions in Arizona and California. Techn. Bull. 4, U. S. Dep. Agr., 14 pp., 7 figs., July. Bugs of genus *Lygus* have been found in stomachs of 26 species of birds; Reduviidae and spiders also noted as enemies (p. 8).

MONTIZAMBERT, ERIC.

1908. Lampyrids and aphids. Can. Ent., vol. 40, no. 1, p. 36, Jan. *Telephorus carolinus* extirpating colonies of *Siphonophora rudbeckiae* (a red aphis).

MOZNETTE, GEO. F.

1915. Notes on the brown lace-wing (*Hemerobius pacificus* Bks.). Journ. Econ. Ent., vol. 8, no. 3, pp. 350-354, pl. 15, June. Number of aphids devoured daily by each of five larvae varied from 24 to 27. Captive.

MYERS, J. G.

1927. The natural enemies of *Dysdercus*. Ann. Ent. Soc. Amer., vol. 20, no. 3, pp. 290-294, Sept. In an article entitled "Ethnological Observations on some Pyrrhocoridae of Cuba," the author reports on observations, published records, and experiments with natural enemies of *Dysdercus*. The actually observed enemies are spiders, pseudoscorpions, thrips (the eggs), tachinid flies, reduviid and other bugs, lizards, and birds.

Reinhard, Edward G.

1925. The wasp *Hoplisus costalis,* a hunter of tree-hoppers. Journ. Washington Acad. Sci., vol. 15, no. 5, pp. 107-110, Mar. 4. An exclusive enemy of Membracidae; 12 species identified from nests.

Sherman, Franklin, Jr.

The harlequin cabbage bug. Bull. North Carolina Dep. Agr., vol. 32, no. 7, pp. 17-24, July. *Murgantia histrionica.* The English sparrow is quite an efficient aid in keeping this pest in check (p. 21).

Smith, Harry S.

1917. Insect parasites and predators as adjuncts in the control of mealybugs. Monthly Bull. California Comm. Hort., vol. 61, nos. 3-4, pp. 108-114, Mar.-Apr. One chrysopid, seven coccinellids, one agromyzid, and one syrphid as predators, and six Hymenoptera as parasites upon species of *Pseudococcus.*

Surface, H. A.

1907. [Enemies of plant lice.] Zool. Bull. Pennsylvania Dep. Agr., vol. 5, no. 3, pp. 81-82, July. Warblers, wrens, titmice, kinglets, chickadees.

1907. [Enemies of the periodical cicada.] Zool. Bull. Pennsylvania Dep. Agr., vol. 5, no. 3, p. 74, July. Skunks, squirrels, moles, chipmunks, pigs, poultry, most birds, snakes (four species mentioned) and turtles listed.

1907. Psyllidae. The jumping plant lice. Zool. Bull. Pennsylvania Dep. Agr., vol. 5, no. 3, pp. 78-79, July. White-breasted nuthatches practically freed an orchard from pear psyllids (*Psylla pyricola*).

Thompson, W. L.

1928. The seasonal and ecological distribution of the common aphid predators of central Florida. Florida Ent., vol. 11, no. 4, pp. 49-52, Feb. *Cycloneda* feeding on seven species of aphids; *Hippodamia* on 5, the larvae averaging 56 and the adults 87 bean aphids per day; *Scymnus* on 5; a few other species briefly mentioned, of which *Coccinella, Rodolia,* and *Chilocorus* are said to be primarily scale devourers.

Webster, F. M.

1897. [Enemies of the periodical cicada.] Bull. 87, Ohio Agr. Exp. Sta., pp. 61-63, Nov. Birds, especially the English sparrow, parasitic flies, dragonflies, soldier-bugs, ground beetles, hogs, and poultry.

1907. [Enemies of the chinch bug.] Bull. 69, U. S. Bur. Ent., pp. 58-59. Birds, frogs, nematodes, ants, ladybeetles, predacious Hemiptera, ground beetles, lacewing flies, spiders, and parasitic fungi.

1909. The Chinchbug (*Blissus leucopterus* Say.). Circ. 113, U. S. Bur. Ent., 27 pp., 8 figs., Nov. Natural enemies, bobwhite (100-400 eaten at a meal), 15 other birds, frogs, ants, ladybirds, anthocorids, carabids, chrysopids, spiders, and diseases.

Wildermuth, V. L.

1915. Three-cornered alfalfa hopper. Journ. Agr. Research, vol. 3, no. 4, pp. 343-362, pl. 43, fig. 1, Jan. *Stictocephala festina.* Spiders, ants, mites, egg parasites, birds, and toads recorded as enemies (pp. 359-360).

WILLIAMS, C. B.

1921. Report on the froghopper-blight of sugar-cane in Trinidad. Mem. 1, Dep. Agr. Trinidad and Tobago, Jan. *Tomaspis saccharina* Distant. Enemies listed are: 2 species of hymenopterous parasites and 2 species of thrips predatory upon the eggs; 3 kinds of birds, 1 syrphid larva, and 1 nematode upon the nymphs; and 17 species of birds, 2 of grasshoppers, 7 of ants, 1 of Lampyridae and 5 of Reduviidae predacious on the adults, besides sundry lizards, toads, frogs, spiders, mites, and two fungoid diseases.

NEUROPTEROIDEA

Insects chiefly predacious in the larval state and often also as imagos. For note on Trichoptera, see Muttkowski and Smith under Miscellaneous Insects.

MCGREGOR, E. A.

1914. Some notes on parasitism of chrysopids in South Carolina. Can. Ent, vol. 46, pp. 306-308, fig 1. Forty-eight out of 99 cocoons were destroyed by hymenopterous parasites.

SMITH, ROGER C.

1922. The biology of the Chrysopidae. Mem. 58, Cornell Univ. Agr. Exp. Sta., pp. 1287-1372, pls. 75-88, figs. 154-163, June. Parasitized in all stages; ladybirds eat the eggs. Certain birds feed on adults. Robber flies noted catching adults and some Hemiptera prey on the larvae.

LEPIDOPTERA

AINSLIE, C. N.

1910. The New Mexico range caterpillar. Bull. 85, U. S. Dep. Agr., pt. 5, pp. 59-96, figs. 1-53, June. *Hemileuca oliviae*—insect parasites, mites, robber flies, and robins recorded as enemies (pp. 88-93).

ALLEN, J. A.

1894. On the mammals of Aransas County, Texas, with descriptions of new forms of Lepus and Oryzomys. Bull. Amer. Mus. Nat. Hist., vol. 6, pp. 165-198. *Onychomys longipes*. Quotes a note from H. P. A[ttwater] to the effect that he found several hundred wings of *Danais archippus*, the bodies of which had been eaten by the *Onychomys*. Allen adds "This observation is of special interest from the fact that this butterfly is supposed to be 'protected' by a nauseous odor or taste that renders it unpalatable to animals" (p. 181).

BADENOCH, L. N.

1899. [Enemies of the lictor moth.] True tales of the insects, p. 215. Notes on hymenopterous and dipterous parasites. The caterpillars of a species may be collected persistently for years for breeding and, because of parasites, none of them reach the perfect stage.

BALL, E. D.

1904. The codling moth. Bull. 87, Utah Exp. Sta., pp. 110-120. Birds, particularly the downy woodpecker and the chickadee, bats, ants, spiders, and predacious insects, recorded as enemies of this pest.

Barber, G. W.

1925. The efficiency of birds in destroying overwintering larvae of the European corn borer in New England. Psyche, vol. 32, no. 1, pp. 30-46. Birds credited with destroying an average of 61 per cent of the larvae in test cases.

Beebe, Wm.

1924. Notes on Galapagos Lepidoptera. Zoologica, vol. 5, no. 3, pp. 51-59, pl. A., Jan. 11. Birds feeding on butterflies (*Callidryas cubule* and *Agraulis vanillae*) and moths. "The relation between birds and butterflies is quite a negligible factor in any lepidopterous theory of evolution of pattern, color, form, or activity" (p. 57).

Bell, E. L.

1924. Notes on *Asilus sericeus* Say (Diptera, Asilidae). Journ. New York Ent. Soc., vol. 32, no. 4, p. 219, Dec. Capturing Hesperiidae, including *Epargyreus tityrus*.

Berger, E. W.

1920. The semitropical army worm. Quart. Bull. Florida State Plant Board, vol. 4, no. 2, pp. 17-34, figs. 4, Jan. *Xylomyges eridania*. Birds, the spined soldier bug, a wasp, tiger beetles, ground beetles, and parasitic insects recorded as enemies (pp. 26-28).

Bird, Henry.

1909. [Enemies of *Papaipema maritima*.] Can. Ent., vol. 41, no. 2, pp. 67-8, Feb. Field mice and skunks. "As very few pupae escape in any locality these animals go over, they become an important factor in the economy of the species."

Breakey, E. P.

1929. Notes on the natural enemies of the iris borer, *Macronoctua onusta* Grote (Lepidoptera). Ann. Ent. Soc. Amer., vol. 22, no. 3, pp. 459-464, Sept. Six species of Diptera, two of Hymenoptera, one beetle, one bird, and rodents.

Britton, W. E.

1906. The gypsy moth and the brown-tail moth. Bull. 153, Connecticut Exp. Sta., p. 7. Several species of parasitic Hymenoptera, Diptera, and predacious insects attack both the gipsy moth and brown-tail moths in Massachusetts; they are also devoured by birds, toads, and other insectivorous animals.

Brooks, Fred E.

1907. The grapevine root-borer. Bull. 110, West Virginia Agr. Exp. Sta., pp. 19-30, 5 pls., Nov. *Memythrus polistiformis* family Sesiidae. Great crested flycatcher feeding upon it (p. 28).

Bryant, Harold C.

1911. The relation of birds to an insect outbreak in northern California during the spring and summer of 1911. The Condor, vol. 13, pp. 195-208, Nov. Stomach examination revealed that four species of birds fed upon the butterflies (*Eugonia californica*), which formed an average of 32.8 per cent of their food. In addition a western flycatcher was observed feeding upon them. Chickens and ducks also reported as taking numbers of these insects.

BURGESS, A. F., AND CROSSMAN, S. S.

1929. Imported insect enemies of the gipsy moth and the brown-tail moth. U. S. Dep. Agr. Techn. Bull. 86, 147 pp., 6 pls., 55 figs. More than 93 million parasites and predators liberated and a high degree of control was obtained by 1924; parasite population fluctuates. Heteroptera, dermestids, spiders, nematodes, mites, birds, and fungi contribute to the mortality, as do starvation and severe weather.

CHITTENDEN, F. H.

1916. The common cabbage worm. Farmers' Bull. 766, U. S. Dep. Agr., p. 9, Nov. The English sparrow, chipping sparrow, and house wren are known to feed upon cabbageworms. It is certain that other species eat them—one instance noted where the pupae were reduced more than 90 per cent by birds.

1922. List of natural enemies of the celery leaf-tyer (*Phlyctaenia rubigalis* Guen.). Can. Ent., vol. 64, no. 8, p. 174, Aug. Twelve hymenopterous parasites.

CLARK, A. H.

1926. Carnivorous butterflies. Smithsonian Rep. 1925, pp. 439-508, figs. 1-5. Lycaenidae feeding on ants or upon ant-tended insects, as aphids, coccids, jassids, and membracids.

COCKERELL, T. D. A.

1898. Preliminary notes on the codling moth. Bull. 25, New Mexico Agr. Exp. Sta., pp. 55-58. Woodpeckers, and quite likely the kinglet, bats, toads, hymenopterous parasites, clerid beetle larvae, and parasitic fungi are recorded as enemies of the codling moth. Mention is also made of the house mouse.

COLLINS, C. W.

1926. Observations on a recurring outbreak of *Heterocampa guttivitta* Walker and natural enemies controlling it. Journ. Agr. Research, vol. 32, no. 7, pp. 689-699, Apr. 1. List of 15 hymenopterous, dipterous, and nematode parasites, and 8 coleopterous, hemipterous, and mammalian predators. Bibliography.

COMSTOCK, J. H.

1879. Report upon cotton insects. U. S. Agr. Comm. 1879, 511 pp., 3 pls., 77 figs. Enemies of the cottonworm (pp. 138-214) include hogs, dogs, cats, raccoons, bats, wild birds, poultry, spiders, *Chrysopa*, dragonflies, mantis, Hemiptera, robber flies, tiger beetles, ground beetles, soldier beetles, ladybirds, boll worms, wasps, ants, chalcid, ichneumonid, and tachinid parasites, flesh flies and phorids.

COOLEY, R. A.

1908. An army cutworm (*Chorizagrotis auxiliaris*). Bull. 71, Montana Exp. Sta., pp. 146-147. Several species of wild birds, domestic fowls, parasitic flies and wasps, besides beetles, are named as foes.

1930. The codling moth. Bull. 42, Montana Exp. Sta., p. 7. Birds considered to be great destroyers of this insect.

CRIDDLE, NORMAN.

1920. Fragments in the life-habits of Manitoba insects—II. Can. Ent., vol. 52, no. 6, pp. 121-125, July. *Protcopteryx oregonana* checked by parasites, Calosoma, and birds.

Crumb, S. E.

1926. Tobacco cutworms and their control. Farmers' Bull. 1494, U. S. Dep. Agr., 13 pp., 11 figs., Aug. Among the agencies of natural control are mentioned spiders, ground beetles, birds, and toads. Birds play an important part.

[Davis, W. T.]

1914. [Dragonflies eating butterflies.] Ent. News, vol. 25, no. 4, p. 191, Apr. Mr. W. T. Davis said "That the dragonflies, especially on the west coast of Florida, were quite a nuisance to collectors on account of their catching many of the smaller butterflies that were disturbed."

Dustan, Alan G.

1923. The natural control of the white-marked tussock moth under city and forest conditions. Proc. Acadian Ent. Soc., vol. 8, 1922, pp. 109-126, pls. 15-16. In the city the principal enemies are parasites of the eggs and larvae, while in the forest, birds, ants, and spiders assume that rôle.

Felt, E. P.

1912. [Green maple worm (*Xylina antennata* Walk.)]. 27th Rep. State Entomologist, 1911, New York State Mus. Bull. 155, pp. 50-51, Jan. Nine species of birds actually observed eating or carrying away caterpillars, and nine others apparently associated in the work.

Floersheim, C.

1906. On some enemies of the diurnal Lepidoptera. Ent. Rec. vol. 18, no. 2, pp. 36-39, Feb. Two cases of birds; predacious beetles very abundant and get many sleeping butterflies. Spiders and coccinellid larvae eat butterfly larvae; eggs destroyed by Hemiptera.

Forbes, S. A.

1883. The regulative action of birds upon insect oscillations. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 6, pp. 1-32, May. Chiefly on birds in relation to an outbreak of cankerworms which made up 35 per cent of food of all birds in the affected orchard. Schedule of all food items identified.

Forbush, E. H.

1899. The destruction of hairy caterpillars by birds. Bull. 20, Div. Ent., U. S. Dep. Agr., pp. 85-93. List of 46 species with detailed notes on feeding habits of some of them, especially in relation to gipsy moth and brown-tail moth larvae, and tent caterpillars.

Garman, H.

1895. [Cutworm enemies]. Bull. 58, Kentucky Exp. Sta., p. 106, Nov. Birds, chickens, turkeys, and pigs, besides insect parasites.

Gibson, Arthur.

1915. The army-worm. Dominion of Canada Dep. Agr., Ent. Branch, Bull. 9, 34 pp., 19 figs. *Cirphis unipuncta*. Many species of wild birds, large numbers of parasitic and predacious insects, domestic poultry, toads, and skunks recorded as enemies. Bacterial and fungous diseases also recorded attacking this worm (pp. 13-17).

GILL, JOHN B.

1913. The fruit-tree leaf roller. U. S. Dep. Agr. Bull. 116, pt. 5, pp. 91-110, pls. 12-16, Mar. *Archips argyrospila*—eight species of birds, parasitic Hymenoptera and Diptera and predacious beetles and ants recorded as enemies; a small mite also noted feeding upon the eggs of the leaf-roller (p. 102).

GILLETTE, CLARENCE P.

1905. The beet webworm. Colorado Agr. Exp. Sta., Bull. 98, pp. 3-12, 2 pls., Mar. *Loxostege sticticalis*. Records of insect-eating birds devouring these in quantities, mention being made of large flocks of blackbirds. Parasitic Hymenoptera also noted (pp. 10-11).

HARDENBERG, C. B.

1912. The willow tree caterpillar (*Angelica tyrrhea*, Cramer). Agr. Journ. South Africa, vol. 4, no. 3, pp. 397-418, Sept. Parasitic flies and wasps attack the caterpillar and eggs. The larvae are reported to be distasteful to birds although they are said to be eaten by some tribes of Kaffirs. Guinea fowls and meerkats feed upon the pupae, and moles probably do so. They are also attacked by a fungus (pp. 412-416).

HASKIN, J. R.

1916. Butterflies as food for squirrels. Ent. News, vol. 27, no. 8, p. 370, Oct. *Melitaea chalcedon*, evidence of destruction of 25 or more by gray squirrels; California.

HERRICK, GLENN W.

1910. The snow-white linden moth. Bull. 286, Cornell Agr. Exp. Sta., pp. 51-64, figs. 54-58, Nov. English sparrow freed cities of this pest—*Ennomos subsignarius* (p. 62).

HORTON, J. R.

1922. A swallow-tail butterfly injurious to California orange trees (*Papilio zolicaon* Boisd.). Monthly Bull. Dep. Agr. California, vol. 11, no. 4, pp. 377-387, Apr. Larvae of *Chrysopa californica* sometimes destroy 80-90 per cent of the eggs. Young caterpillars eaten by same foe, also by *Zelus renardi*, and a hymenopterous parasite; the pupa by *Chalcis ovata* (p. 385).

HOWARD, L. O.

1904. The insect book. The Nature Library, vol. 8, pp. 56-57. Parasitic Hymenoptera attacking the cotton caterpillar; an instance of destruction of 95 per cent of the eggs.

HOWARD, L. O. AND CHITTENDEN, F. H.

1907. The catalpa sphinx (*Ceratomia catalpae* Bdv.). Circ. 96, U. S. Bur. Ent., p. 6. Cuckoos, the catbird and the Baltimore oriole recorded as enemies.

1909. The green-striped maple worm (*Anisota rubicunda* Fab.). Circ. 110, U. S. Bur. Ent., p. 5. Domestic fowls and nine species of wild birds recorded as enemies.

JOHNSON, E. E.

1926. Birds eating butterflies. The Field, London, vol. 147, p. 658, Apr. 15. Observations made of a stonechat taking butterflies.

KERSHAW, JOHN C. W.

1905. Butterfly-destroyers in Southern China. Trans. Ent. Soc. London, 1905, pp. 5-8. Has seen only a dozen attacks by birds in five years; lizards destroy most adults. Notches in wings made by striking twigs, etc., a cuckoo the worst enemy of larvae, taking even the hairy and most conspicuous kinds. Also ants fastening on butterfly tongues.

KIRKLAND, A. H.

1896. The army worm. Massachusetts Crop Rep. 1896, pp. 34-36. Birds are recognized as being the most important enemies of the army worm. Toads, parasitic flies, and beetles also are recorded as being enemies of this pest.

LAMBORN, W. A.

1912. Butterflies a natural food of monkeys. Trans. Ent. Soc. London, 1912, p. iv. Mangabeys eating butterflies at mudholes.

LAWSON, G.

1888. Insect injuries to field and orchard crops. Provincial Crop Rep. Nova Scotia, 1888, p. 29. American and forest tent caterpillars are eaten by the crow and cuckoo and to a lesser extent by the linnet and swallow; cankerworms by the linnet (purple finch?).

LINTNER, J. A.

1888. Cutworms. Bull. 6, New York State Mus., 36 pp., 28 figs. Natural enemies include wild birds, poultry, toads, ground beetles, predacious bugs, mites, spiders, parasitic Diptera and Hymenoptera (pp. 23-28).

LOUNSBURY, C. P.

1895. Canker worms, army worms, etc. Bull. 28, Hatch Exp. Sta., p. 15. Poultry, birds, frogs, toads, beetles, and parasitic flies listed as foes.

LUGGER, OTTO.

1892. Tent-caterpillars. Ann. Rep. Minnesota Hort. Soc., p. 372. Cuckoos, skunks, and Calosoma are enemies.

MALLONEE, A. M.

1916. Frogs catching butterflies. Science, n. s., vol. 43, pp. 386-387, Mar. 17. *Rana catesbiana* eating a number of *Papilio turnus*.

MALLY, F. W.

1893. Report on the boll worm of cotton (*Heliothis armiger* Hubn.). Bull. 29, U. S. Div. Ent., p. 26. Woodpeckers and sparrows reported as enemies.

MANDERS, N.

1912. [Enemies of *Danais chrysippus*.] Trans. Ent. Soc. London, p. 446. *Trichogramma evanescens* parasitizes large numbers of eggs; ants eat the eggs; larvae are commonly parasitized; spiders and ants eat them; they are cannibalistic; adults eaten by lizards, and sometimes by birds.

MARLATT, C. L. AND ORTON, W. A.

1906. The control of the codling moth and apple scab. Farmers' Bull. 247, U. S. Dep. Agr., p. 9. Woodpeckers noted as preying upon the codling moth.

McAtee, W. L.

1912. Bird enemies of the codling moth. Yearbook U. S. Dep. Agr. 1911, pp. 237-246. Birds recognized as most effective natural enemies—from 66 to 85 per cent of the hibernating larvae recorded as being destroyed. 36 species of birds known to prey upon this moth.

1923. Another insect birds should not eat. The Auk, vol. 40, no. 3, p. 560, July. Red-humped apple caterpillar (*Schizura concinna*)—recorded as preyed upon by six species of birds.

1924. Birds as factors in the control of the fall webworm. The Auk, vol. 41, no. 2, p. 372, Apr. Results of eight years' study in Canada, red-eyed vireo destroys 11.4 to 89.5 per cent of the broods, averaging more than 68 per cent; birds "tremendously important" in control of the insect.

1925. Economic ornithology. The Auk, vol. 42, no. 3, pp. 464-465, July. European corn borer—This pest is recorded as preyed upon by four species of birds.

1926. Birds feeding on the European corn borer. The Auk, vol. 43, no. 3, p. 395, July. Red-wing blackbirds and downy woodpeckers recorded as feeding on the larvae.

1927. Economic ornithology in recent entomological publications. The Auk, vol. 44, no. 3, pp. 458-459, July. European corn borer recorded as taken by six species of birds.

Neal, H. V.

1912. Monkeys eating butterflies. Trans. Ent. Soc. London, 1912, pp. xvii-xviii. Commonly do so in Lagos.

Otanes, F. O.

1925. The rice stem borer (*Schoenobius incertellus* Walker). Philippine Agr. Rev., vol. 18, no. 1, pp. 81-82. "The adult moths are said to be preyed upon by birds, mudfish (dalag), spiders, frogs, and mantids" (p. 82).

Pack, H. J.

1922. Toads in regulating insect outbreaks. Copeia, no. 107, pp. 46-47, June 20. Feeding exclusively on sugar-beet webworms and taking from 20 to 40 each.

Patch, Edith M.

1908. The saddled prominent, *Heterocampa guttivitta* (Walker). Maine Agr. Exp. Sta., Bull. 161, pp. 311-350, figs. 14-40, Nov. Predacious bugs and beetles, hymenopterous parasites, a fungus, skunks, domestic fowls, and wild birds recorded as enemies. (Pp. 340-348.)

1921. A meadow caterpillar. Bull. 302, Maine Agr. Exp. Sta., pp. 309-320, 2 pls., Dec. *Ctenucha virginica*. One dipterous and 5 hymenopterous parasites. "Though covered with stiff hairs, the over-worked theory that such caterpillars are thereby immune from birds' attacks cannot stand up against the testimony of my pet thrush which whips these caterpillars vigorously against the floor of the cage until, in a surprisingly short time, their bodies are beaten limp and naked, whereupon they are swallowed in one gulp."

Pettit, R. H.

1904. The codling moth in Michigan. Bull. 222, Michigan Agr. Exp. Sta., pp. 78 and 89-90. Birds most important; shrews, parasitic Hymenoptera and fungi also mentioned.

Phillips, W. J. and King, Kenneth M.

1923. The corn earworm. Farmers' Bull. 1310, U. S. Dep. Agr., 17 pp., 18 figs., Jan. *Heliothis obsoleta.* Seventeen species of birds, egg parasites, and other parasitic insects, certain ants, and spiders recorded as foes. The earworms' cannibalistic habit is the most important factor in reducing its attacks on corn (pp. 10-12).

Phipps, C. R.

1927. The black army cutworm. Maine Agr. Exp. Sta., Bull. 340, pp. 201-216, figs. 29-30, May. *Agrotis femnica.* Three kinds of flies and one of wasp parasites, predators including bugs, beetles, wasps, and birds recorded as enemies (pp. 212-213).

Plank, H. K.

1929. Natural enemies of the sugar cane moth stalkborer in Cuba. Ann. Ent. Soc. Amer., vol. 22, pp. 621-640, 7 figs. Its burrowing habit is "an admirable protection against direct, or artificial, but does not seem to afford any great amount of protection against the attack of a rather formidable array of natural enemies." Tachinids, sarcophagids, and Hymenoptera recorded as parasites, and earwigs, beetles, and ants as predators. Bibliography.

Poos, F. W.

1928. An annotated list of some parasitic insects. Proc. Ent. Soc. Washington, vol. 30, no. 8, pp. 145-150, Nov. Parasites varying from 1 to 14 in number bred from each of 19 hosts, mostly Lepidoptera.

Poulton, E. B.

1911. The attacks of tachinid flies upon the African Danaine genus *Amauris.* Trans. Ent. Soc. London, 1911, p. xcix. Twenty out of 25 pupae of *Amauris psyttalea* parasitized; another lot all parasitized. This a good indication enemies of adults are scarce; otherwise species would be rare.

Quaintance, A. L.

1908. The apple-tree tent caterpillar (*Malacosoma americana*). Circ. 98, U. S. Bur. Ent., p. 6. Black-billed and yellow-billed cuckoos, blue-jay, crow, chickadee, Baltimore oriole, red-eyed vireo, chipping sparrow, and yellow warbler mentioned as enemies; also the common toad.

Sanderson, E. D.

1903. The codling moth. Bull. 59, Delaware Agr. Exp. Sta., pp. 7-8. Parasitic worms and insects, soldier beetles, named as enemies as well as 10 or more species of birds which are the most efficient.

1905. The gipsy moth in New Hampshire. Bull. 121, New Hampshire Agr. Exp. Sta., p. 99. Ground beetles, parasitic insects, and several species of birds are recorded as preying upon the gipsy moth.

1906. The brown-tailed moth in New Hampshire. Second report. Bull. 122, New Hampshire Agr. Exp. Sta., p. 127. Parasitic insects, predacious bugs, toads, bats, and several species of birds, particularly the English sparrow, recorded as enemies.

1909. The codling moth and how to control it by spraying. Bull. 143, New Hampshire Agr. Exp. Sta., pp. 64-82. Downy woodpeckers and nuthatches are recorded as being the most important enemies of the codling moth.

SANDERSON, E. D., HEADLEE, T. J., AND BROOKS, CHARLES.

1907. Spraying the apple orchard. Bull. 131, New Hampshire Agr. Exp. Sta., pp. 18-19 and 35. Woodpeckers and nuthatches are recorded as feeding extensively on the codling moth.

SAUNDERS, ARETAS A.

1916. A note on the food of the western robin. The Condor, vol. 18, no. 9, p. 81, Mar.-Apr. Robin feeding on *Papilio rutulus*, and a chipmunk feeding upon the same species and also on *P. eurymedon*.

SHARP, D.

1910. [Parasites of winter moth.] Cambridge Nat. Hist., vol. 5, p. 521. "The destructive winter moth—*Cheimatobia brumata*—is known to be subject to the attacks of 63 species of Hymenopterous parasites. So abundant are these latter that late in the autumn it is not infrequently the case that the majority of caterpillars contain these destroyers."

SHERMAN, F.

1921. Observations of natural enemies of the fall cankerworm (*Alsophila pometaria* Peck) in forests of southern Alleghany Mountains in 1920. Journ. Econ. Ent., vol. 14, no. 6, pp. 478-481, Dec. Names 15 species of birds presumably of material help, five predacious insects, and 3 parasites of which one destroyed from 25 to 40 per cent of the eggs.

SHIRAS, GEO., 3RD.

1921. Frogs eating butterflies. Nat. Geogr. Mag., vol. 40, no. 2, p. 174, Aug. Leopard frogs catching about 500 "blues" in a week; also eating many *Argynnis aphrodite*.

SKAIFE, S. H.

1921. Some factors in the natural control of the wattle bagworm. South African Journ. Sci., vol. 17, nos. 3-4, pp. 291-301, July. *Acanthopsyche junodi* Heylaerts. Out of a total of 59,687 examined, just over one per cent were destroyed by birds and rats, 19 per cent by insect parasites, 16 per cent by fungous disease, and 17 per cent by other diseases. Only one-quarter of one per cent survive the early perils of their life.

SMITH, J. B.

1895. [*Zeuzera pyrina*.] 15th Ann. Rep. New Jersey Exp. Sta. 1894, pp. 531-532. Almost all insectivorous birds, especially woodpeckers and the sparrow, in addition to bats, and predacious insects, are recorded as enemies of this insect.

SPENCER, G. J. AND H. G. CRAWFORD.

1923. The European corn borer in Ontario. Ontario Dep. Agr. Bull. 295, 11 pp., 10 figs., Mar. Ants, aphis-lions, ladybird beetles, ground beetles, crickets, a parasitic fly, and several species of birds noted as foes. One instance recorded of downy and hairy woodpeckers destroying 60 per cent of the borers (pp. 7-8).

Tothill, John D.

1922. The natural control of the fall webworm [*Hyphantria cunea* Drury] in Canada together with an account of its several parasites. Dep. Agr. Dominion of Canada, Bull. 3, n. s. (techn.), 107 pp., 6 pls., 99 figs. Tabulations of the destruction by various enemies in different localities and years; birds average most important, parasites sometimes important, sometimes not.

1923. Notes on the outbreaks of spruce budworm, forest tent caterpillar, and larch sawfly in New Brunswick. Proc. Acadian Ent. Soc., vol. 8, 1922, pp. 172-182. Spruce budworm. Natural checks effective in New Brunswick were eggs, larvae, and pupal parasites, spiders, and birds; and in British Columbia, parasites and birds. Nothing of importance on enemies of the other forms.

Trouvelot, Leopold.

1868. The American silkworm. Amer. Nat., vol. 1, pp. 30-38, 85-94, 145-149. *Telea polyphemus*. Thrushes, catbirds, orioles; 95 out of a hundred worms become the prey of these feathered insect hunters.

U. S. Entomological Commission.

1883. 3rd Rep. U. S. Ent. Comm., p. 125. All insectivorous birds, hogs, chickens, turkeys, toads, and frogs prey upon the armyworm. "The worms themselves, when hard pushed, will even devour each other."

1883. 3rd Rep. U. S. Ent. Comm., pp. 175-178. Forty or more species of wild birds, notable mention being made of bluebirds, cedarbirds and butcherbirds, and parasitic and predacious insects, also hogs, are recorded as enemies of the cankerworm.

1885. 4th Rep. U. S. Ent. Comm., pp. 87-90. More than 20 species of wild birds, poultry, hogs, raccoons, skunks, opossums, bats, tree frogs, lizards, spiders, and numerous kinds of predacious insects are recorded as preying upon the cottonworm.

Vickery, R. A.

1929. Studies on the fall army worm in the Gulf Coast District of Texas. Techn. Bull. 138, U. S. Dep. Agr., 63 pp. Numerous hymenopterous parasites sometimes destroy 40-50 per cent of the caterpillars.

Warren, B. H.

1897. The army worm. Ann. Rep. Pennsylvania State Coll. 1896, pp. 164-220, 16 pls. Much on natural enemies including tachinids and ichneumonids, ground beetles, birds, mammals, and toads.

Webster, R. L.

1909. The lesser apple leaf-folder. Iowa State Coll. Exp. Sta. Bull. 102, pp. 181-212, figs. 1-13, Mar. *Peronea minuta*—tachinid and hymenopterous parasites recorded as the most important natural enemies although birds and diseases are also important factors (pp. 206-211).

Weed, C. M.

1899. The forest tent caterpillar. Bull. 64, New Hampshire Agr. Exp. Sta., pp. 77-98, figs. 20-33, Apr. *Clisiocampa disstria*—preyed upon by insects, spiders, toads, and birds. Ten kinds of birds feeding on larvae, one on the cocoons and four on the adults.

1899. The spiny elm caterpillar. Bull. 67, New Hampshire Agr. Exp. Sta., pp. 125-141, figs. 40-51, Oct. *Vanessa antiopa*—egg parasites chalcid, ichneumonid and tachinid flies on caterpillars; *Calosoma*, wasps, cuckoos, and toads named as enemies (pp. 138-140).

1900. Insect record for 1899. Bull. 72, New Hampshire Exp. Sta., pp. 64-65. The Baltimore oriole and the cuckoos are especially noted as enemies of tent caterpillars.

1900. The forest tent caterpillar. Second report. Bull. 75, New Hampshire Exp. Sta., pp. 120-121. Eighteen or more species of birds are recorded as preying upon these caterpillars.

1902. [Enemies of cankerworms.] Bull. 90, New Hampshire Agr. Exp. Sta., 1902, p. 35, Mar. Robins, bluebirds, cedarbirds, and many others feed freely upon the pests.

West, L. S.

1923. Immunity to parasitism in *Samia cecropia* Linn. (Lep.: Saturniidae; Dip.: Tachinidae.) Ent. News, vol. 34, no. 1, pp. 23-25, Jan. Ineffectiveness of attack of 35-40 tachinid larvae; nevertheless lists two Tachinidae and eight species of Hymenoptera that do successfully parasitize this host.

Yothers, M. A.

1913. *Eugonia californica* Bdv. in the Pacific Northwest. Can. Ent., vol. 45, no. 12, pp. 421-422, Dec. "I think that the total disappearance of these caterpillars and chrysalids was no doubt due to birds" (p. 422).

Young, R. A.

1907. Insects affecting the poplar. Proc. Columbus Hort. Soc. 1906, pp. 68-82. Birds constitute an important agency in keeping the *Hemerocampa leucostigma* in check (p. 74).

COLEOPTERA

Agassiz, L., and Cabot, J. Elliot.

1850. Lake Superior, etc., p. 72. *Monochamus scutellaris* preyed upon by Canada jay and two species of *Picoides*.

Blackman, M. W.

1915. Observations on the life history and habits of *Pityogenes hopkinsi* Swaine. Techn. Publ. no. 2, New York State Coll. Forestry, pp. 11-66, 6 pls., Nov. Natural enemies include beetles, mites, and parasitic Hymenoptera (pp. 53-56).

Britten, H.

1926. A pentatomid bug preying on beetle larvae. North Western Nat., vol. 1, p. 38. *Rhacognathus punctatus* found sucking larvae of beetle (*Hydrothassa marginella*).

1927. Red ants and beetles. North Western Nat., vol. 2, p. 256. *Myrmica ruginodis* killing beetles (*Melandrya caraboides*).

Brooks, F. E.

1919. The flat-headed apple-tree borer. Farmers' Bull. 1065, U. S. Dep. Agr., 12 pp., 13 figs. *Chrysobothris femorata*. Woodpeckers, and other birds, ants, and six species of hymenopterous parasites recorded as enemies (p. 9).

Burgess, A. F. and Collins, C. W.

1917. The genus *Calosoma,* including studies of seasonal histories, habits, and economic importance of American species north of Mexico and of several introduced species. Bull. 417, U. S. Dep. Agr., 124 pp., 19 pls., 5 figs. Caterpillars the principal food of these beetles; cannibalism, and attacks of toads, skunks, and birds the chief organic checks; predatory bugs, and parasitic flies also noted (pp. 10-13).

Cartwright, Oscar L.

1929. The maize billbug in South Carolina. Bull. 257, South Carolina Agr. Exp. Sta., 35 pp., 13 figs., May. Natural enemies (p. 31) include egg parasite, predacious beetles, ants, and wasps.

Chamberlin, F. S., and Tenhet, J. N.

1923. The tobacco flea-beetle in the southern cigar-wrapper district. Farmers' Bull. 1352, U. S. Dep. Agr., 9 pp., 8 figs. *Epitrix parvula.* A spider, lygaeid bug, and birds noted as enemies (p. 5).

Chittenden, F. H.

1911. Notes on various truck-crop insects. Bull. 82, pt. 7, U. S. Bur. Ent., pp. 85-93, fig. 24. Natural enemies of *Leptinotarsa decemlineata,* pp. 85-88; 1 beetle, 3 hemiptera, 16 wild birds, and guinea fowls.

1926. Notes on the behavior of *Cotinis nitida* L. and its bird enemies. Proc. Biol. Soc. Washington, vol. 39, pp. 15-17, Feb. Starling and cardinal eat it.

Chittenden, F. H., and Fink, D. E.

1922. The green June beetle. Bull. 891, U. S. Dep. Agr., 52 pp., 10 pls., 7 figs. *Cotinis nitida.* Natural enemies (pp. 31-37) include parasitic flies, digger wasps, ground beetles, mites, various mammals, and birds; fungal and bacterial diseases also noted.

Chittenden, F. H., and Marsh, H. O.

1920. The western cabbage flea-beetle. U. S. Dep. Agr. Bull. 902, 21 pp., 4 figs., 1 pl., Oct. *Phyllotreta pusilla.* Hymenopterous and worm parasites recorded as well as 12 species of birds feeding on beetles of this genus.

Davis, John J.

1913. Common white grubs. U. S. Farmers' Bull. 543, 20 pp., 12 figs., July. More than 60 species of birds, domestic fowls, skunks, a number of predacious and parasitic insects recorded preying upon white grubs at one stage or another (pp. 13-15).

Fenton, F. A., and Dunham, E. W.

1929. Biology of the cotton boll weevil at Florence, S. C. Techn. Bull. 112, U. S. Dep. Agr., 75 pp., 35 figs. Considerable variation exists in mortality rate from parasitism (by three species of Hymenoptera) from as low as 2.37 to as high as 51.52 per cent; predators, heat, proliferation by the plant, disease and unknown causes take their toll, the average total from all these causes being about 40 per cent; then from the number that go into hibernation only an average of 3.27 per cent survive.

FEYTAUD, JEAN.

1922. Le Doryphore, Chrysomèle nuisible à la pomme de terre (*Leptinotarsa decemlineata* Say). Rev. Zool. Agr. Appl., vol. 21, Numero special, 48 pp., 13 figs., Aug. Natural checks include skunks, birds, snakes, frogs, spiders, phalangids, mites, beetles, bugs, wasps, robber flies, and parasitic flies (pp. 14-17).

FORBES, S. A.

1880. Notes upon the food of predacious beetles. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 3, pp. 149-152, Nov. Both vegetable and animal, the latter including beetles, larvae, and plant lice.

1880. Notes on insectivorous Coleoptera. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 3, pp. 153-160, Nov. Carabidae, Lampyridae, Coccinellidae, from stomach examination. Animal food, mites and their eggs, ants, caterpillars, beetles and their larvae, plant lice, and centipeds.

1883. The food relations of the Carabidae and Coccinellidae. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 6, pp. 33-64, May. Report on dissections of 175 Carabidae and 39 Coccinellidae. Animal food included Hymenoptera, Lepidoptera, Diptera, Neuroptera, and Coleoptera, spiders, mites, myriapods, mollusks. Notes on birds as enemies of Cicindelidae and Carabidae.

1907. On the life history, habits, and economic relations of the white-grubs and may beetles. Bull. 116, Illinois Agr. Exp. Sta., pp. 447-480, Aug. Principal enemies, swine, crows, blackbirds, and *Tiphia;* other parasites *Macrophthalma, Sparnopolius, Pyrgota,* and *Ophion* (pp. 468-475).

FORBUSH, E. H.

1912. 4th Ann. Rep. State Ornithologist Mass., 1911, 32 pp., 4 pls., 9 figs. *Galerucella luteola.* Cedar waxwing clearing trees of infestations of the elm leaf beetle (pp. 19-20).

HESS, WALTER N.

1920. The ribbed pine borer. Mem. 33, Cornell Agr. Exp. Sta., pp. 367-381, pl. 8, figs. 61-66. *Rhagium lineatum.* Woodpeckers, most important; a parasite reared (pp. 378-379).

HOPKINS, A. D.

1896. The relation of insects and birds to present forest conditions. Proc. Amer. Forestry Assoc., vol. 11, pp. 175-176. Woodpeckers recorded as enemies of bark and clerid beetles.

HYSLOP, JAMES A.

1912. The false wireworms of the Pacific Northwest. Bull. 95, pt. 5, U. S. Bur. Ent., pp. 73-87, figs. 22-27. Numerous species of birds, horned-toads, garden toads, skunks, parasites, and disease recorded as enemies (pp. 84-86).

1915. Wireworms attacking cereal and forage crops. Bull. 156, U. S. Dep. Agr., 34 pp., 8 figs. Elateridae—a long list of bird enemies given; horned-toads, mites, predacious flies, hymenopterous parasites, nematodes, fungi (pp. 25-29).

INGRAM, J. W.

1927. The striped blister beetle on soy beans. U. S. Dep. Agr. Leafl. 12, 5 pp., 3 figs. *Epicauta lemniscata*—three species of birds and a robber fly named as enemies.

KALMBACH, E. R.

1914. Birds in relation to the alfalfa weevil. Bull. 107, U. S. Dep. Agr., 64 pp., 5 pls. Forty-five species of birds found to feed on this comparatively recently introduced pest; also domestic fowls, toads, frogs, salamanders, horned-toads, snakes, and shrews.

MCATEE, W. L.

1914. Bird enemies of Diabroticas. The Auk, vol. 31, no. 1, p. 120, Jan. Southern corn root worm (*Diabrotica duodecim-punctata*) recorded as preyed upon by 24 species of birds; western corn root worm (*Diabrotica longicornis*) taken by the nighthawk and the wood pewee.

1915. Bird enemies of two beetle pests. The Auk, vol. 32, no. 3, pp. 377-378, July. *Oncideres putator*—it is believed that the southern downy woodpecker and the Texas woodpecker attack the larvae of this pest. *Monocrepidius vespertinus*—the records show that these beetles are devoured by eight species of birds.

MAIL, G. ALLEN.

1930. Winter soil temperatures and their relation to subterranean insect survival. Journ. Agr. Research, vol. 41, no. 8, pp. 572-592, Oct. 15. Few parasites; mites, birds, fungal and bacterial diseases reduce them, but climate a control factor of much importance.

MUIR, F.

1917. The introduction of *Scolia manilae* Ashm. into the Hawaiian Islands. Ann. Ent. Soc. Amer., vol. 10, no. 2, pp. 207-210, June. A parasite of the beetles *Anomala orientalis* and *Adoretus tenuimaculatus*.

[NELSON, E. W.]

1921. Report of chief of Bureau of Biological Survey, 34 pp. Bird enemies of the Japanese beetle (*Popillia japonica*) mentioned (p. 14); five species of birds and the toad listed.

QUAINTANCE, A. L., AND JENNE, E. L.

1912. The plum curculio. Bull. 103, U. S. Bur. Ent., 250 pp., 20 pls., 33 figs. Natural enemies (pp. 139-154) include an egg parasite, hymenopterous and dipterous parasites of later stages, ants, chrysopids, carabids, lampyrids, fowls and wild birds; also the toad.

SATTERTHWAIT, A. F.

1919. How to control billbugs destructive to cereal and forage crops. Farmers' Bull. 1003, U. S. Dep. Agr., 23 pp., 24 figs. Insect, worm, and fungus parasites, toad and bird predators mentioned, the birds apparently most important (pp. 19-20).

SCHUSTER, W.

1909. [Beetles and their enemies in the bird world.] Ent. Blätt. Nürnberg, vol. 5, no. 7, pp. 142-144, July 15. Birds the principal enemies of beetles; notes on European bird foes of various families of beetles; similar notes for Lepidoptera.

SLINGERLAND, M. V.

1906. The bronze birch borer: an insect destroying the white birch. Bull. 234, Cornell Agr. Exp. Sta., pp. 65-78, figs. 31-38. *Agrilus anxius*. Woodpeckers and chalcid parasites mentioned as foes.

THOMAS, C. A.

1931. The predatory enemies of Elateridae (Coleoptera). Ent. News, vol. 42, no. 5, pp. 137-140, May; no. 6, pp. 158-167, June. Mites, pseudoscorpions, spiders, hemiptera, beetles, flies, hymenoptera, amphibians, reptiles, birds, and mammals; birds most important; predators more effective than parasites. Bibliography.

WEBB, J. L.

1906. The western pine-destroying bark beetle. Bull. 58, pt. 2, U. S. Bur. Ent., pp. 17-30, pls. 2-3, figs. 7-12. *Dendroctonus brevicornis*. Woodpeckers destroyed large percentage in some trees (p. 27).

WEBSTER, F. M.

1880. Notes upon the food of predacious beetles. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 3, pp. 149-152, Nov. Chiefly on vegetarian Carabidae but notes on carnivorous species of Carabidae, Staphylinidae, and Lampyridae; the prey mentioned includes plant lice, cricket, grasshopper, and beetles.

1892. Underground insect destroyers of the wheat plant. Bull. Ohio Agr. Exp. Sta., vol. 5, no. 9, pp. 221-247, 8 figs., Dec. Wireworms—crows, thrushes, robins, blackbirds (p. 228). Whitegrubs—poultry, crows, jays, nighthawks, robin, catbird, brown thrasher, wood thrush, red-headed woodpecker; swine, bats, badger, weasel, martin, rat, skunk, raccoon, fox, mole, frogs, digger wasps, robber flies, and fungi (pp. 236-237).

1913. The southern corn rootworm, or budworm. U. S. Dep. Agr. Bull. 5, 11 pp., 2 figs., Sept. *Diabrotica 12-punctata*—12 species of birds and parasitic flies (pp. 9-10).

1913. The western corn rootworm. Bull. 8, U. S. Dep. Agr., 8 pp., 5 figs., Sept. *Diabrotica longicornis* preyed upon by nighthawks, wood pewees, a parasitic fly, and chinch bug fungus (p. 6).

WILDERMUTH, V. L.

1910. The clover-root curculio. Bull. 85, pt. 3, U. S. Bur. Ent., pp. 29-38, figs. 15-19. *Sitones hispidulus*—14 species of birds recorded as enemies (p. 37).

WILSON, C. B.

1923-1924. Life history of the scavenger water beetle *Hydrous* (*Hydrophilus*) *triangularis*, and its economic relations to fish breeding. Bull. Bur. Fisheries, vol. 39, pp. 9-38, 22 figs. Food of larvae, snails, midge larvae, fishes, other water beetle larvae, tadpoles, and several groups of insects and crustaceans in smaller quantity. Food of adults, vegetable matter, fishes. Enemies of *Hydrophilus* include cannibalistic larvae, dragonfly nymphs, frogs, fishes, birds. Bibliography.

1923-1924. Water beetles in relation to pondfish culture, with life histories of those found in fishponds at Fairport, Iowa. Bull. U. S. Bur. Fisheries, vol. 39, pp. 231-345, figs. 1-143. Larvae highly cannibalistic, dragonfly nymphs are enemies, as are also, mites, hydra, ants, fishes, turtles, frogs, and snails; foes of pupae include hymenopterous parasites, horse fly larvae, and ants; of adults, turtles, fishes, birds, toads, and frogs. Notes are given on the feeding

habits of the larvae and adults of a number of water beetles; fish destruction not so apparent as would have been inferred from previous literature. Bibliography.

MECAPTERA

Predacious.

DIPTERA

ALEXANDER, CHARLES P.

1920. The crane-flies of New York. Mem. 38, Cornell Univ. Agr. Exp. Sta., pp. 699-1132, pls. 12-97, June. Ninety-one species of birds, besides foxes, mice, shrews, moles, amphibians, fishes, mites, spiders, dragonflies, Diptera, Coleoptera, Hymenoptera, Protozoa recorded as enemies of crane flies in one stage or another (pp. 721-734).

BROMLEY, S. W.

1923. Observations on the feeding habits of robber flies. Part I. Psyche, vol. 30, no. 2, pp. 41-45, Apr. Tabulation of the prey of 26 *Proctacanthus rufus,* all Hymenoptera and in 14 cases honey bees. Six records for *P. brevipennis* include three of beetles, one ant, one blow fly, and one assassin bug.

1930. Bee-killing robber flies. Journ. New York Ent. Soc., vol. 38, no. 2, pp. 159-176, pl. 10, June. Especially the honey bee; review of records from various countries; discussion of the U. S. species, with notes on other kinds of prey taken by some of them. The Dasypogoninae tend to favor Hymenoptera, the Laphriinae beetles, while the Asilinae are more general feeders.

BURRILL, A. C.

1913. Economic and biologic notes on the giant midge: *Chironomus* (*Tendipes*) *plumosus* Meigen. Bull. Wisconsin Nat. Hist. Soc., vol. 10, nos. 3-4, pp. 124-163, Apr. Swallows, red-winged blackbirds as enemies (p. 146); other notes in annotated bibliography refer to fishes, birds, Utricularia, and fungi as natural checks.

1913. Notes on Lake Michigan swarms of chironomids; quantitative notes on spring insects. Bull. Wisconsin Nat. Hist. Soc., vol. 11, nos. 1-2, pp. 52-69, June. Enemies of adults include mites, spiders, ants, and birds (pp. 66-67).

COCKERELL, T. D. A.

1894. On the habits of some Asilidae. Ent. News, vol. 5, no. 6, pp. 173-174, June. *Mallophora fautrix* eating *Odynerus* sp.; *Mallophora* sp. eating honey bee; *Proctacanthus philadelphicus* preying upon *Erax dubius,* and butterfly, *Synchloe lacinia* var. *crocale*; *Proctacanthus milberti* preying upon *Bembex* sp. and honey bee; *Promachus princeps* preying upon *Odynerus annulatus.*

CUTHBERTSON, ALEXANDER.

1926. The trout as a natural enemy of crane-flies. Scottish Nat., 1926, pp. 85-88. *Salmo fario* an important consumer of crane flies in all stages; earthworms, phalangids, and click beetles also in the stomachs.

1926. Spiders as enemies of crane-flies. Scottish Nat., 1926, pp. 127-129. List of species that eat crane flies, of which the names are given. Special study of the prey found in webs of the wood spiders *Zilla atrica* and *Z. x-notata.*

HARSHBARGER, W. A.

1894. The bold robber-fly and the mantis. Ent. News, vol. 5, no. 6, p. 169, June. Asilid attacked mantis (*Stagmomantis carolina*) but was itself captured and partly eaten.

HILDEBRAND, S. F.

1919. Fishes in relation to mosquito control in ponds. Rep. U. S. Comm. Fisheries 1918, App. 9, 15 pp., 18 figs.

HINE, JAMES S.

1906. Habits and life histories of some flies of the family Tabanidae. Bur. Ent., U. S. Dep. Agr., Techn. Bull., no. 12, pt. 2, pp. 19-38, 12 figs., Aug. Birds, hornets, and spiders noted as enemies.

HOWARD, L. O.

1904. The insect book. The Nature Library, vol. 8, pp. 158-159. Outbreaks of the armyworm sometimes completely controlled by tachina flies. They also attack grasshoppers, bugs, and beetles, sawflies and sawfly larvae and bumble bees and wasps.

1910. Preventive and remedial work against mosquitoes. Bull. 88, U. S. Bur. Ent., 126 pp., June 20. Use of natural enemies, salamanders, dragonflies, predacious mosquitoes and fish (pp. 62-72).

HYSLOP, J. A.

1910. The smoky crane-fly. Bull. 85, pt. 7, U. S. Bur. Ent., pp. 119-132, figs. 60-66. *Tipula infuscata*. Natural enemies include a tachinid parasite, ground beetles, ants, mites, and birds; a long list is given of birds that feed on crane flies; fungi also kill the insects.

LEATHERS, A. L.

1922. Ecological study of aquatic midges and some related insects with special reference to feeding habits. Bull. U. S. Bur. Fisheries, 38, Doc. no. 915, 61 pp., 44 figs., May. Food includes Protozóa, small Crustacea, diatoms, algae, and other vegetation.

MATHESON, ROBERT.

1929. A handbook of the mosquitoes of North America. 268 pp., 25 pls. Food; suck blood of mammals, birds, amphibians, and snakes (pp. 39-41); enemies, birds, bats, fishes, tadpoles, salamanders, and insects (pp. 71-72).

SMITH, K. M.

1927. A study of *Hylemyia* (*Chortophila*) *brassicae* Bouche, the cabbage root fly, and its parasites. With notes on some other dipterous pests of cruciferous plants. Ann. Appl. Biol., vol. 14, pp. 312-330. Description of life-history, enemies, and parasites. The larvae of a small beetle (*Aleochara bilineata*) destroy the pupae of the fly; while a cynipid and a braconid parasitize the larvae, which are also eaten by the carnivorous larva of an anthomyiid fly. The larva of the beetle is itself parasitized by a proctotrupid.

TWINN, C. R.

1931. Observations on some aquatic animal and plant enemies of mosquitoes. Can. Ent. 63, no. 3, pp. 51-61, Mar. Other mosquito larvae, water beetle larvae, dragonfly and damselfly nymphs, backswimmers, water-scorpions, caddis larvae, salamanders, fishes, hydras, and bladderworts. Bibliography.

Van Dine, D. L.

1907. The introduction of top-minnows (natural enemies of mosquitos) into the Hawaiian Islands. Press Bull. 20, Hawaiian Agr. Exp. Sta., 10 pp., 3 figs., July 25.

Weed, C. M.

1902. [Enemies of *Bibio albipennis.*] Bull. 90, New Hampshire Agr. Exp. Sta., pp. 32-33, Mar. Fishes eating those falling in lake; chief food of robin in early spring.

HYMENOPTERA

Beilawsky, A. G.

1927. [Enemies of bees.] Vragi Pchet, Leningrad, 204 pp., 2 pls., 148 figs. Mammals, birds, reptiles, amphibians, insects, arachnids, worms, and protozoans.

Bequaert, J.

1922. The predacious enemies of ants. Bull. Amer. Mus. Nat. Hist., vol. 45, pp. 271-331, pls. 24-25, Oct. Spiders, beetles, ant-lions, Diptera, Hymenoptera, amphibians, lizards, birds and mammals, including man, discussed at length. "There is certainly little or no evidence to show that, as the theory is often expressed, ants are unpalatable to most insectivorous animals" (p. 271).

Bigelow, N. K.

1922. Insect food of the black bear (*Ursus americanus.*) Can. Ent., vol. 54, no. 3, pp. 49-50, Mar. *Vespula diabolica, V. consobrina,* and ants; notes on observations of others.

Davis, Wm. T.

1919. A remarkable nest of *Vespa maculata,* with notes on some other wasps' nests. Bull. Brooklyn Ent. Soc., vol. 14, nos. 4-5, pp. 119-123, Oct.-Dec. Notes on food habits of *Vespa* spp., cannibalistic, eat flies and damselflies; robber flies are their enemies.

1924. Oak apple galls destroyed by gray squirrels. Bull. Brooklyn Ent. Soc., vol. 19, no. 3, pp. 91-93, 1 fig., June. *Amphibolips confluens* freely eaten.

Graham, S. A.

1928. The influence of small mammals and other factors upon the larch sawfly survival. Journ. Econ. Ent., vol. 21, no. 2, pp. 301-310, Apr. *Lygaeonematus erichsoni.* Small mammals, probably *Microtus* chiefly, destroy from 50 to 80 per cent of the hibernating cocoons; parasites and fungi about 10 per cent.

Groneman, Carl F.

1923. Birds as destroyers of gall insects. Audubon Bull. (Illinois Audubon Soc.), pp. 13-15, 6 figs., Fall issue. Birds and squirrels recorded as enemies.

Heikertinger, Franz.

1919. Die metöke Myrmekodie. Tatsachenmaterial zur Lösung des Mimikryproblems. Biol. Zentralbl., vol. 39, no. 2, pp. 65-102, Feb. Enemies of ants (pp. 81-100), insects, spiders, amphibians, reptiles, mammals, birds.

HERSEY, J. L.

1873. Bees and kingbirds. Can. Ent., vol. 5, pp. 159-160. Kingbirds and purple martins feed on honey bees, mostly drones; kingbirds feed freely on dragonflies also.

HOWARD, L. O.

1904. [Prey of Proctotrypoidea.] The insect book, p. 51. Gall flies, gall gnats, butterflies, moths, beetles, and the eggs of spiders, bugs, butterflies, and moths.

HUNTER, W. D.

1912. Two destructive Texas ants. U. S. Dep. Agr., Bur. Ent. Circ. 148, 6 pp., Apr. *Pogonomyrmex barbatus molefaciens.* Eight species of birds and the horned lizard recorded as enemies.

ISELY, DWIGHT.

1913. The biology of some Kansas Eumenidae. Kansas Univ. Sci. Bull., vol. 8, no. 7, pp. 235-309, pls. 34-37, July. Prey includes larvae of several families of Lepidoptera, of two of beetles, and of sawflies. Bibliography.

PHILLIPS, E. F.

1917. Beekeeping. Chap. 22, Bee diseases and enemies, pp. 397-416. Three diseases of the brood, two of adults; enemies include two wax moths, toads, birds, mice, rats, and other small mammals, certain spiders and mites, dragonflies, various Hemiptera, the death's head moth, Mediterranean flour moth, a dipterous parasite (*Braula caeca*), blister beetle (*Meloe*) and other beetles, wasps, hornets, and ants. "Dragonflies are so destructive to queens as to make queen-rearing unprofitable in some places."

SHARP, D.

1910. [Summary of the prey of Fossores.] Cambridge Nat. Hist., vol. 6, pp. 92-93. General notes on prey of 16 families of wasps.

1910. [Prey of Ichneumonidae.] Cambridge Nat. Hist., vol. 5, p. 551. "Most of the species, in the larval state, live inside the larvae of Lepidoptera, and they thus keep the myriads of caterpillars within bounds, the number of these destroyed by ichneumons being prodigious. Some of the family are, however, external parasites, and some are known to attack spiders and insects of other Orders than Lepidoptera."

SWENK, M. H.

1910. A new sawfly enemy of the bull pine in Nebraska. Rep. Nebraska Agr. Exp. Sta., pp. 3-33, 18 figs. *Diprion* n. sp.—natural checks include ichneumonids, tachinids, chipmunks, birds, and a bacterial disease.

WILLIAMS, F. X.

1913. Monograph of the Larridae of Kansas. Kansas Univ. Sci. Bull., vol. 8, no. 4, pp. 121-213, pls. 22-30, July. Prey includes Orthoptera chiefly, but also Hemiptera, and spiders. Bibliography.

1913. Notes on the habits of some wasps that occur in Kansas. Kansas Univ. Sci. Bull., vol. 8, no. 6, pp. 223-230, pl. 33, fig. 1, July. *Harpactus* preying upon *Gypona cinerea, Mimesa* upon *Athysanus exitiosus* and other jassids; *Prionyx* upon locusts.

ARACHNIDA

Bilsing, S. W.

1920. Quantitative studies in the food of spiders. Ohio Journ. Sci., vol. 20, no. 7, pp. 215-260, May. Summarizes a large number of observations on prey actually seen eaten by spiders, and upon insects found in their webs; gives also some experimental results.

Calvert, Philip P.

1923. Studies on Costa Rican Odonata. *X. Megaloprepus,* its distribution, variation, habits, and food. Ent. News, vol. 34, no. 6, (Food), pp. 171-174, June. Feeds on spiders.

Lincecum, G.

1867. The tarantula killers of Texas. Amer. Nat., vol. 1, no. 3, pp. 137-141, May. *Pompilus formosus* Say feeds on *Mygale hentzii* and other large spiders.

Lovell, J. H.

1915. Insects captured by the Thomisidae. Can. Ent., vol. 47, no. 4, pp. 115-116, pl. 2, Apr. Crab spiders prey upon butterflies, dragonflies, wasps, bumble bees, honey bees, and large flies.

McAtee, W. L.

1911. Bird enemies of the Texas-fever tick and other ticks. The Auk, vol. 28, no. 1, pp. 136-138, Jan. A résumé of seven publications on the subject; of the birds mentioned, 12 species are inhabitants of the United States.

Savory, Theo. H.

1928. The biology of spiders. 376 pp., 16 pls., 121 figs., London. Food (pp. 116-125), flies, wasps, bees, ants, beetles, earwigs, butterflies, moths, harvestmen, woodlice, and other spiders; more rarely caterpillars, worms, fish, birds. "They show no trace of discrimination." Enemies (pp. 176-179) include birds, toads, lizards, mammals, harvestmen, spiders, wasps, and ichneumon flies, and other parasites.

MOLLUSCA

Baker, F. C.

1916. The relations of mollusks to fish in Oneida Lake. Techn. Publ. no. 4, New York State Coll. Forestry, 366 pp., 50 figs., one table, one map, July. On pp. 154-218 is summarized information on food of 54 species of fresh-water fishes, especially in relation to mollusks.

1918. The relation of shellfish to fish in Oneida Lake, New York. Circ. 21, New York State Coll. Forestry, pp. 11-33, figs. 1-16, Aug. Some snails carnivorous, eating other snails, leeches, and small fish; shellfish form a large part of the food of many species of fishes; other enemies of shellfish include flukes, dragonfly nymphs, horse fly larvae, water bugs, water beetle larvae, leeches, crawfishes, frogs, salamanders, turtles, ducks, other water birds, muskrats, mink and otter.

Bequaert, J.

1925. The arthropod enemies of mollusks, with description of a new dipterous parasite from Brazil. Journ. Parasitol., vol. 11, pp. 201-212, fig. 1. Carnivorous snails probably the most important predatory

enemies; predacious beetles, mites, and dipterous parasites also numbered among their foes. Bibliography which is abstracted in the paper.

BISHOP, SHERMAN C.

1921. The map turtle, *Graptemys geographica* (Le Sueur) in New York. Copeia, no. 100, pp. 80-81, Nov. 15. Feeding on *Unio complanatus*.

CHURCHILL, E. P., AND LEWIS, SARA I.

1924. Food and feeding in fresh-water mussels. Bull. U. S. Bur. Fisheries, vol. 39, 1923-1924, pp. 439-471, figs. 1-26. Protozoa, diatoms, other algae, organic detritus. Bibliography on the food of fresh-water mussels, and upon that of lamellibranchs in general.

COOKE, A. H.

1895. [Enemies of mollusca.] Cambridge Nat. Hist., vol. 3, pp. 56-62. Birds, rats, frogs, toads, beetles, mongooses, monkeys, walruses, whales, fishes, other mollusks, trematodes, nematodes, and mites.

DYCHE, L. L.

1903. Notes on the food habits of California sea-lions (*Zalophus californianus* Lesson.) Trans. Acad. Sci. Kansas, 1901-1902, pp. 179-182. Food found in numerous stomachs, chiefly squids.

FEDERIGHI, HENRY.

1930. Control of the common oyster drill. Econ. Circ. 70, U. S. Bur. Fisheries, 7 pp., 5 figs. *Urosalpinx cinerea* "destroys oysters to the value of several million dollars annually in the United States" (p. 1).

FIELD, IRVING A.

1911. The food value of sea mussels. Bull. U. S. Bur. Fisheries, vol. 29, 1909, pp. 85-128, pls. 18-25. Food (pp. 92-95), mostly diatoms and Protozoa. Enemies (pp. 95-97), are numerous, fishes, mollusks, sea-stars, crows, rats, parasitic crabs.

FORREST, H. E.

1927. Fishes, Caradoc and Severn Valley Field Club, record of bare facts for the year 1926, p. 19. Stomach of an eel (*Anguilla vulgaris*) from the Severn was full of small bivalves (*Sphaerium corneum*).

HERRINGTON, WM. C.

1930. The Pismo clam. Fish. Bull. 18, California Div. Fish and Game, 69 pp., 16 figs. *Tivela stultorum*—birds, rays, starfish, and marine snails are enemies (pp. 52-54).

MOORE, H. F.

1908. Volumetric studies of the food and feeding of oysters. Bull. U. S. Bur. Fisheries, 28, pp. 1297-1308, pl. 125, 6 figs. Ninety-five per cent diatoms; remainder of equally minute plants and animals.

RITCHIE, J.

1927. A remarkable whale invasion. Scottish Nat. 1927, pp. 161-163. A school of false killers (*Pseudorca crassidens*) visited the Dornoch Firth in October, 1927, and some of them ran aground there. This whale is very rare, and had hardly been seen anywhere for 80 years (a few appeared off Western Europe in 1861 and 1862, and it was also seen in Tasmania). Examination of these whales showed they feed mainly on large cuttlefish.

Stevenson, Charles H.

1892. A bibliography of publications in the English language relative to oysters and the oyster industries. Extract from Rep. U. S. Comm. Fish and Fisheries for 1892, art. 3, pp. 305-359. Some of the papers referred to deal with the food and enemies of oysters.

Stiles, Ch. Wardell.

1902. Frogs, toads, and carp (*Cyprinus carpio*) as eradicators of fluke disease. Ann. Rep. U. S. Bur. Animal Industry 1901, pp. 220-222, figs. 197-203. By feeding on snails the intermediate hosts.

PISCES

Adams, Chas. C., and Hankinson, T. L.

1928. The ecology and economics of Oneida Lake fish. Roosevelt Wild Life Ann., vol. 1, nos. 3-4, pp. 242-548, 1 pl., figs. 179-244, Nov. Notes on food and enemies of most of the species; full bibliography.

Allin, A. E.

1929. Seining records and food of the intermediate stages of Lake Erie fishes. Suppl. 18th Ann. Rep. New York Conserv. Dep. 1928, pp. 95-106. Cyprinidae and Catostomidae feed on algae and diatoms; the smaller Percidae on crustaceans and insect larvae, and the larger Percidae, Esocidae, and Catostomidae (fish eggs) on smaller fishes and fish eggs.

Annin, J.

1902. In Rhead, Louis, The speckled brook trout, pp. 129-140. Winged enemies include night heron, kingfisher, ducks, loons, grebes, fish hawk, bald eagle and barred owl.

Baker, F. C.

1918. The productivity of invertebrate fish food on the bottom of Oneida Lake, with special reference to mollusks. Techn. Publ. no. 9, New York State Coll. Forestry, 264 pp. Notes on food of five species of fishes (pp. 214-216). Bibliography.

Barbour, T.

1921. Spiders feeding on small cyprinodonts. Psyche, vol. 28, no. 4, pp. 131-132, Aug. *Dolomedes tenebrosus.*

Bigelow, N. K.

1924. The food of young suckers (*Catostomus commersonii*) in Lake Nipigon. Univ. Toronto Studies, no. 24, Publ. Ontario Fish Res. Lab., no. 21, pp. 81-115. Rotifers, Cladocera, insects.

Breder, C. M., Jr.

1921. The food of *Mustelus canis* (Mitchill) in mid-summer. Copeia, no. 101, pp. 85-86, Dec. 20. Notes on contents of 102 stomachs. (Fish in 10, crabs 44, *Nereis* sp. 1, univalves and vegetable matter 3.)

1922. Observations on young bluefish. Copeia, no. 106, pp. 34-36, May 20. Contents of 15 stomachs listed; 86 per cent fishes.

Breder, C. M., Jr., and Crawford, D. R.

1922. The food of certain minnows. A study of the seasonal dietary cycle of six cyprinoids with especial reference to fish culture. Zoologica, vol. 2, no. 14, pp. 287-327, figs. 101-128, Aug. *Semotilus bullaris,* 87 per cent insects, including larvae and adults of several orders plus some worms, millipeds, crayfish; *Leuciscus vandoisulus,* 98

per cent insects together with worms, spiders, crayfish and slug; *Notropis procne,* 36 per cent insects and in addition some worms and water mites; *Notropis cornutus* and *Rhinichthys atronasus,* 57 per cent insects plus same additional items as in last; *Exoglossum maxillingua,* 35 per cent insects, plus worms and fish eggs. Most of the insects were terrestrial species.

CARR, A. M.

1908. Food of fishes. Rep. Sci. Invest. Northumberland Sea Fisheries Comm. 1907, pp. 68-71. Reports on stomach examinations of 10 species.

1909. The food and condition of fish obtained from the North-east coast. Rep. Sci. Invest. Northumberland Sea Fisheries Comm. 1908-1909, pp. 41-50. Stomach analyses of seven species of fishes (pp. 43-46).

CHAMBERLAIN, F. M.

1907. Some observations on salmon and trout in Alaska. U. S. Bur. Fisheries, Doc. 627, 112 pp., 5 pls. Enemies (pp. 107-109) include trout, sculpins, mergansers, golden-eyes, mallards. The trout feed on other fishes, insects and their larvae, snails, and bivalves.

COLE, LEON J.

1905. The German carp in the United States. Rep. U. S. Comm. Fisheries 1904, pp. 523-641, pls. 1-3. Considerable on food and economic relations. Bibliography.

DERYKE, WILLIS.

1922. The food of the fishes of Winona Lake. Indiana Dep. Conserv., 47 pp., 1 pl., 1 map. Notes on 17 species, 6 of which are treated in some detail; yellow perch: young, midge larvae, Entomostraca, amphipods; adults, chiefly fish; bluegill: young, chiefly midge larvae and Entomostraca; older, the same plus caddis larvae, insects, snails; large-mouth black bass: young, amphipods, Cladocera, mayfly and midge larvae; larger, chiefly fish; log perch: amphipods, Cladocera, midge, caddis, and mayfly larvae, snails; skipjack: chiefly nonaquatic insects; sunfish: snails, midge larvae, insects; hogmolly: midge, and mayfly larvae, oligochaetes. Bibliography.

EATON, E. H.

1928. The Finger Lakes fish problem. Suppl. 17th Ann. Rep. New York Conserv. Dep. 1927, pp. 40-46. Tabulation of food of some 30 species, 3 of which are almost exclusive fish-eaters, 7 others largely so, 8 feed chiefly on larval, and 5 on flying insects. Six species eat many scuds, and 4 even as adults, subsist more or less on plankton Crustacea. Enemies of fish, besides their own kind, include lampreys, turtles, snakes, loons, grebes, and mergansers.

ELMHIRST, RICHARD.

1926. Notes on fishes from the Firth of Clyde. Scottish Nat., pp. 151-158, and 179-186. Full notes on food of cod and briefer reference to that of some other species. Nine kinds of fishes (including itself) listed as predatory on herring.

Elrod, M. J.

1929. The fishes of Flathead Lake. Montana Wild Life, vol. 2, no. 1, pp. 6-9, June. Notes on food of: *Catostomus* spp.: Insects, Entomostraca; *Ptychocheilus oregonensis:* Mainly insects such as mayfly and caddisfly larvae, grasshoppers, some fish and shrimps; *Mylocheilus caurinus:* Entomostraca and insects; *Leuciscus gillu:* Entomostraca and insects; *Salmo clarkii:* Beetles, mayflies, grasshoppers; *Salvelinus malma:* Fishes including *Coregonus* and *Ptychocheilus; Coregonus williamsoni:* Larvae of Tipulidae, Simuliidae, *Planorbis, Physa; Micropterus salmoides:* Fish, insects.

Field, Irving A.

1907. Unutilized fishes and their relation to the fishing industry. U. S. Bur. Fisheries Doc. no. 622, 50 pp. Notes on the food of eight species.

Forbes, S. A.

1880. The food of fishes. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 3, pp. 18-65, Nov. Notes on stomach examinations for numerous species.

1883. The food of the smaller fresh-water fishes. Bull. Illinois State Lab. Nat. Hist., vol. 1, no. 6, pp. 65-94, May. Examination of 319 stomachs representing 25 species; food chiefly neuropteroid and chironomid larvae, and Entomostraca; other animal items, fishes, mollusks, Hymenoptera, Diptera, Coleoptera, Hemiptera, Thysanura, Arachnida, amphipods, isopods, worms, and protozoans.

1890. Studies of the food of fresh-water fishes. Bull. Illinois State Lab. Nat. Hist. vol. 2, pp. 433-473. Many stomach examinations of 28 species; tabulation of items and percentages.

1890. On the food relations of fresh-water fishes. Bull. Illinois State Lab. Nat. Hist., vol. 2, pp. 475-538. Summary of the preceding papers, discussion of fishes as predators on other fishes, on mollusks, insects, crustaceans, worms, fresh-water sponges, and protozoans. Schedule of food items and the species taking them.

Fulton, T. Wemyss.

1903. The distribution, growth, and food of the angler (*Lophius piscatorius.*) 21st Ann. Rep. Fishery Board Scotland 1902, pp. 186-217. Analyses of 280 stomach contents; 269 containing fishes, 10 squids, and 1 a crab.

Gudger, E. W.

1927. Hydras as enemies of young fishes. Nat. Hist., vol. 27, pp. 270-274, 3 figs.

1929. Wide-Gab, the angler fish. Nat. Hist., vol. 29, no. 2, pp. 155-159, illus., Mar.-Apr. Case of attempt to swallow a gull; review of literature, showing that birds up to the size of the loon are eaten; seven wild ducks from one stomach; the principal food, however, is fishes.

Hankinson, Thomas L.

1908. A biological survey of Walnut Lake, Michigan. Rep. Biol. Surv. Michigan Geol. Surv. 1907, pp. 158-288, pls. 13-75. Food of several species of fishes noted from examination of stomachs (pp. 200-216).

HARNELL, J., AND NAYUDO, M. R.

1924. A contribution to the life history of the Indian sardine, with notes on the plankton of the Malabar Coast. Madras Fisheries Bull. 17, pp. 129-197, 10 pls. Food extensively treated; consists of diatoms, peridineans, infusorians, Heliozoa, larval bivalves, and copepods.

HILDEBRAND, S. F., AND TOWERS, I. L.

1927. Food of trout in Fish Lake, Utah. Ecology, vol. 8, no. 4, pp. 389-397, Oct. Contents of 181 stomachs tabulated, the more important items being *Daphnia, Gammarus,* midges and vegetation; leeches, snails, dragonfly nymphs, and fishes and their eggs are other items of the food.

JOHANSEN, FRITS.

1912. The fishes of the Danmark Expedition. Danmark-Ekspeditionen Gronl. Nordostkyst 1906-1908, vol. 5, no. 12, pp. 633-675, 5 figs., pls. 44-46. Notes on the food of *Gadus* and *Salmo.*

JOHNSON, ROBERT S., AND STAPLETON, M. F.

1917. Fish ponds on farms. App. 2, Rep. U. S. Comm. Fisheries 1915, 29 pp. Cannibalistic and other predacious fishes, turtles, snakes, birds, and minks are the principal foes.

JUDAY, CHANCEY.

1906. A study of Twin Lakes, Colorado, with especial consideration of the food of the trouts. Bull. U. S. Bur. Fisheries, vol. 26, pp. 147-178, pl. 3. In addition to notes on contents of 370 trout stomachs of six species this publication contains a good bibliography and a digest of papers relating to Entomostraca as food of fishes.

KENDALL, WILLIAM C.

1897. Notes on the food of four species of the cod family. Rep. U. S. Fish Comm. 1896, App. 3, pp. 177-186. A long list of food items. "Protective mimicry seems of little avail against these fishes."

KENDALL, WILLIAM C., AND DENCE, W. A.

1927. A trout survey of the Allegany State Park in 1922. Roosevelt Wild Life Bull., vol. 4, no. 3, pp. 291-482, figs. 54-86, tables, July. Notes on 112 stomach contents (pp. 472-474, table 27): Midges, caddisflies, beetles, ants and other Hymenoptera, Diptera, grasshoppers, plant lice, lacewing flies, stoneflies, mayflies, spiders, crustaceans, and fish. Bibliography.

KNIGHT, A. P.

1927. Losses in speckled trout fry after distribution. Science, n. s., vol. 65, pp. 525-526, Aug. Losses 71-98 per cent, mostly to natural enemies, birds, trout and other fishes.

KRAATZ, WALTER C.

1923. A study of the food of the minnow *Campostoma anomalum.* Ohio Journ. Sci., vol. 33, pp. 265-283. Diatoms, algae, etc.

LEBOUR, MARIE V.

1924. The food of young herring. Journ. Marine Biol. Assoc. United Kingdom, n. s., vol. 13, pp. 325-330. Among animal items, Infusoria, larval mollusks, copepods.

Lewis, Ralph C.

1929. The food habits of the California sardine in relation to the seasonal distribution of microplankton. Bull. Scripps Inst. Oceanography, Techn. Ser. 2, pp. 155-180, 2 figs. Items of animal food are schizopods and copepods.

Linton, Edwin.

1901. Fish parasites collected at Woods Hole in 1898. Bull. U. S. Fish Comm., vol. 19, 1899, pp. 267-304, pls. 33-43. Notes on fish food, pp. 270-284.

1901. Parasites of fishes of the Woods Hole region. Bull. U. S. Fish Comm., vol. 19, 1899, pp. 405-492, pls. 1-34. Summary of parasites, pp. 425-488, contains many references to food of fishes.

1921. Food of young winter flounders. Rep. U. S. Comm. Fisheries, App. 4, 14 pp. *Pseudopleuronectes americanus,* food of young principally amphipods, other small Crustacea, and annelids; food of adults, annelids, Crustacea, ascidians, fish, mollusks. Almost as much on parasites (Sporozoa, trematodes, nematodes, and Acanthocephala) as on food.

MacCoy, Clinton V.

1929. The mackerel in New England. Bull. Boston Soc. Nat. Hist., vol. 53, pp. 3-7, Oct. Food, small fish, squids, pteropods, amphipods, copepods. Enemies, whales, porpoises, sharks, dogfish, bluefish, gannets, parasitic worms.

Marshall, W. S., and Gilber, N. C.

1905. Notes on the food and parasites of some fresh-water fishes from the lakes at Madison, Wis. Rep. U. S. Comm. Fisheries 1904, App., pp. 513-522. Incidental notes on food.

Moore, J. Percy.

1922. Use of fishes for control of mosquitoes in northern fresh waters of the United States. Rep. U. S. Comm. Fisheries, App. 4, 60 pp., 7 pls. Food of roach: Entomostraca, insects, mites, Protozoa; mudminnow: Insects, Crustacea, mollusks, Protozoa; killifish: Oligochaetes, mollusks, Entomostraca; top minnow: cannibalistic; blue-spotted sunfish: Midge larvae, Entomostraca, amphipods; long-eared sunfish: Midge larvae, Entomostraca, oligochaetes; common sunfish: Midge larvae, Entomostraca, snails, mites, tadpoles. All eat mosquito larvae. Bibliography.

Muttkowski, Richard A.

1925. The food of trout in Yellowstone National Park. Roosevelt Wild Life Bull., vol. 2, no. 4, pp. 471-497, figs. 114-133, Feb. Stoneflies, 90 per cent; mayflies, caddisflies, adults and young of all; and water-trapped land insects.

1929. The ecology of trout streams in Yellowstone National Park. Roosevelt Wild Life Ann., vol. 2, no. 2, pp. 155-240, figs. 53-116, Oct. Food of trout, pp. 222-230, conclusions as in his 1925 paper on the subject. Food of insects, pp. 230-233; see under Muttkowski and Smith.

Needham, James G.

1903. Food of brook trout in Bone Pond. Bull. 68, New York State Mus., pp. 204-217. Contents of 25 stomachs tabulated.

NEEDHAM, JAMES G.; JUDAY, CHANCEY; MOORE, EMMELINE; SIBLEY, CHAS. K.; AND TITCOMB, JOHN W.

1922. A biological survey of Lake George, N. Y. N. Y. State Conserv. Comm., 78 pp., 27 figs. Much on the food of fishes; the staples of the diet of carnivorous fry are waterfleas, midges (all stages), other insects, scuds (amphipods), and crayfishes; cannibalism prevalent (p. 63); food of adults of eight species outlined on pp. 65-68. Lake trout: Principal food, lake smelt, other items yellow perch, and caddisflies; black bass: Perch, crawfish, grasshoppers, scuds; pike: Other fishes; yellow perch: Staples, midge larvae, mayfly nymphs, scuds, snails, secondary, caddisworms and waterfleas; bullhead: Scuds, midge larvae, mayfly nymphs, snails; long-eared sunfish: Mayfly nymphs, midge larvae, ants, scuds, waterfleas, miscellaneous insects, and crayfishes; common sunfish: Snails, mayfly nymphs, caddisworms, beetles, midge larvae, various insects; rock bass: Crayfish, fishes, insects.

NEEDHAM, P. R.

1929. Quantitative studies of the fish food supply in selected areas. Suppl. 18th Ann. Rep. New York Conserv. Dep. 1928, pp. 220-232. Ithaca, N. Y., Erie-Niagara watershed. Foods consumed by trout in comparison with available foods; in the case of aquatic foods the relation of consumption to availability is very clear. This is a reworking of a similar paper in the 17th Ann. Rep. (1927) 1928, pp. 192-206.

NEW YORK CONSERVATION DEPARTMENT.

1928. A biological survey of the Oswego River System. Suppl. 17th Ann. Rep. New York Conserv. Dep. 1927, 248 pp., 12 col. pls., text figs., maps. Much on fish food; in a tabulation of food items of adults of 31 species, midges, mayflies, and minnows seem to be most commonly used; and of young of eight species, copepods, Cladocera, and midges.

PAGE, WM. F.

1895. Feeding and rearing fishes, particularly trout, under domestication. Bull. U. S. Fish Comm., 1894, pp. 289-314. Some notes on natural food, and an indexed bibliography.

PATTERSON, A. H.

1926-1927. Food of the Sturgeon. Trans. Norfolk and Norwich Nat. Soc., vol. 12, pp. 380-381. Stomach of one contained about 729 small fish (lesser sandlaunces).

PEARSE, A. S.

1915. On the food of the small shore fishes in the waters near Madison, Wisconsin. Bull. Wisconsin Nat. Hist. Soc., vol. 13, no. 1, pp. 7-22, 1 fig., Mar. Sixteen species, of which nine lived largely on insects and their larvae, two on ostracods, two on copepods, and one on Cladocera.

1918. The food of the shore fishes of certain Wisconsin lakes. Bull. U. S. Bur. Fisheries, vol. 35 (1915-16), pp. 249-292. Report on more than 1,600 specimens of 32 species, with bibliography.

1919. Habits of the black crappie in inland lakes of Wisconsin. Rep. U. S. Comm. Fisheries 1918, app. 3, pp. 5-16. Tabulation of contents of 276 stomachs.

1921. Distribution and food of the fishes of Green Lake, Wis., in summer. Bull. U. S. Bur. Fisheries, vol. 37, 1919-1920, pp. 255-272, 1 map. Notes on 16 species; the food of all combined comprised insect larvae 21.7 per cent, amphipods 16.5 per cent, fish 9.6 per cent, crayfishes 7.8 per cent, cladocerans 7.6 per cent, insect pupae 6.7 per cent, snails 4.4 per cent, bivalves 4.1 per cent, and the following items in smaller proportions, adult insects, ostracods, oligochaetes, leeches, mites, *Mysis*, and copepods. Sixty-seven per cent is arthropods, composed of 31.7 insects and 35.6 crustaceans. Comparison is made with the fishes of Lake Mendota. Bibliography.

1924. Amount of food eaten by four species of fresh-water fishes. Ecology, vol. 5, no. 3, pp. 254-258, July. Order of choice, minnows, earthworms, amphipods, dragonfly nymphs, crayfishes, grasshoppers, snails, and caddis larvae.

Pearse, A. S., and Achtenberg, Henrietta.

1917-1918. Habits of yellow perch in Wisconsin Lakes. Bull. U. S. Bur. Fisheries, vol. 36, 1917-1918, pp. 297-366, pl. 83, figs. 1-35. Report on 1,147 stomach examinations of which the food as a whole was made up of 38.3 per cent insect larvae, 21.4 Entomostraca, 9.5 insect pupae and adults, 5.5 macroscopic crustaceans, 4.5 fishes, 2.4 mollusks, 1.4 oligochaetes, leeches and arachnids. Enemies of the perch include pickerel, black bass, a number of birds, and a variety of parasites. Bibliography.

Pearson, John C.

1928. Natural history and conservation of the redfish and other commercial sciaenids of the Texas coast. Bull. U. S. Bur. Fisheries, vol. 44, pp. 129-214, 44 figs. *Sciaenops ocellatus:* Shrimps, crabs, mollusks, fish; *Pogonias cromis:* Clams, mussels, oysters, crabs, shrimps, fish, annelids; *Cynoscion nebulosus:* Shrimps, crabs, fish; *Micropogon undulatus:* Shrimps, crabs, annelids, fish.

Peck, James I.

1894. On the food of the menhaden. Bull. U. S. Fish Comm., vol. 13, 1893, pp. 113-126, pls. 1-8. Food filtered from water by gill-raker mechanism, consists chiefly of unicellular organisms, both animal and vegetable. They also take ostracods, copepods, amphipods and other small Crustacea, and young *Nereis*. Composition of food the same as material filtered from water by mechanical contrivances: Diatoms, rotifers, dinoflagellates, etc. The supply of such food illimitable.

1896. The sources of marine food. Bull. U. S. Fish Comm., 1895, pp. 351-368, pls. 64-71. Plankton, largely diatoms, the basis; notes on the food of the squeteague, the bluefish, sea bass, scup, and tautog.

Petersen, C. G. J.

1894. On the biology of our flat-fishes. Rep. Danish Biol. Sta., vol. 4, 1893, pp. v+146,2 pls., 1 map, 18 tables. Notes on food of young and adults.

Scott, Andrew.

1899. Observations on the habits and food of young fishes. Proc. & Trans. Liverpool Biol. Soc., vol. 13, 1898-99, pp. 90-93.

Scott, Thomas.

1902. Observations on the food of fishes. 20th Ann. Rep. Fishery Board Scotland 1901, pt. 3, pp. 486-538. Notes on 56 species.

1903. Some further observations on the food of fishes, with a note on the food observed in the stomach of a common porpoise. 21st Ann. Rep. Fishery Board Scotland 1902, pp. 218-227, 2 figs.

Sibley, C. K.

1929. The food of certain fishes of the Lake Erie Drainage Basin. Suppl. 18th Ann. Rep., New York Conserv. Dep. 1928, pp. 180-188. Thirty-four species feed mainly on immature aquatic insects, especially midge larvae, and Crustacea; eight species are pronounced spawn-eaters; small fish are important food of the larger species; food of young chiefly copepods and Cladocera.

Smallwood, W. M., and Struthers, P. H.

1927. Carp control studies in Oneida Lake. Suppl. 17th Ann. Rep., New York Conserv. Dep., pp. 67-83. Much on food; animal matter taken by adults includes fish, ostracods, phyllopods, copepods, crayfish, midge and caddis larvae and other insects; by young, ostracods, copepods, Cladocera, insect larvae, snails, worms, mites, eggs of snails, insects and copepods, rotifers, and bivalves.

Smith, Hugh M.

1896. A review of the history and results of the attempts to acclimatize fish and other water animals in the Pacific States. Bull. U. S. Fish Comm., vol. 15, 1895, pp. 379-472, pls. 73-83. Notes on food of a few species. Catfish, fish eggs and fry; carp, spawn; shad, shrimps; striped bass, carp, catfish, crabs.

Smith, W. Ramsay.

1889. On the food of fishes. 7th Ann. Rep. Fishery Board Scotland 1888, pp. 222-258.

1890. On the food of fishes. 8th Ann. Rep. Fishery Board Scotland 1889, pp. 230-256.

1891. On the food of fishes. 9th Ann. Rep., Fishery Board Scotland 1890, pp. 222-242.

1892. On the food of fishes. 10th Ann. Rep. Fishery Board Scotland 1891, pp. 211-231. This and similar papers in three previous reports are based on investigations of Thomas Scott.

Stewart, N. H.

1926. Development, growth, and food habits of the white sucker, *Catostomus commersonii* Lesueur. Bull. U. S. Bur. Fisheries, vol. 42, pp. 147-184, 55 figs. Among animal food midge larvae are most important at all ages; some rotifers, Entomostraca, and Protozoa are taken at all stages also, but dragonfly, caddisfly, mayfly larvae, and Mollusca are taken only by adults. Bibliography.

Struthers, P. H.

1929. Carp control studies in the Erie Canal. Suppl. 18th Ann. Rep. New York Conserv. Dep. 1928, pp. 208-219. Animal food (p. 214) includes insect larvae, snails, midge larvae, bivalves, ostracods, Malacostraca, copepods, Cladocera, and decapods.

Sumner, Francis B.; Osburn, Raymond C.; and Cole, Leon J.
1911. A biological survey of the waters of Woods Hole and vicinity. Bull. U. S. Bur. Fisheries, vol. 31, pt. 2. The catalogue of the marine fauna, fishes, pp. 734-744, contains notes on the food mainly quoted from Verrill, Goode, Linton, and Field.

Taverner, P. A.
1915. The double-crested cormorant (*Phalacrocorax auritus*) and its relation to the salmon industries on the Gulf of St. Lawrence. Can. Geol. Surv., Bull. 13, 24 pp., 1 pl. Food sculpins, herring, capelin, eel, etc., no salmon; the salmon feeds on other fishes, and crustaceans, and is cannibalistic.

Tiffany, Lewis H.
1921. Algal food of the young gizzard shad. Ohio. Journ. Sci., vol. 21, no. 4, pp. 113-122, Feb. Mentions several game fishes that prey on this wholly vegetarian species.

Turner, Clarence L.
1920. Distribution, food and fish associates of young perch in the Bass Island region of Lake Erie. Ohio Journ. Sci., vol. 20, no. 5, pp. 137-152, Mar. Details of analyses of 138 stomach contents.
1921. Food of the common Ohio darters. Ohio Journ. Sci., vol. 22, pp. 41-62. Usually the food changes with age from Entomostraca to midge larvae and similar organisms, and then with maturity, to a varied diet in which ephemerid and other large insect larvae predominate.
1922. Notes on the food habits of young *Cottus ictalops* (miller's thumb). Ohio Journ. Sci., vol. 22, pp. 95-96. Midge and other insect larvae.

Verrill, A. E.
1873. Report upon the invertebrate animals of Vineyard Sound and the adjacent waters, with an account of the physical characters of the region. Report on Sea Fisheries of New England, pt. 1, pp. 295-778. Lists of species found in the stomach of fishes (pp. 514-521).

Warren, B. H.
1897. Fish-eating birds and mammals. Ann. Rep. Pennsylvania Dep. Agr., 1896, pp. 297-303, 1 pl. Seventeen or more kinds of birds, wild cats, raccoons, muskrats, mink, and the otter.

Welsh, Wm., and Breder, C. M., Jr.
1923-1924. Contributions to life histories of *Sciaenidae* of the eastern United States coast. Bull. U. S. Bur. Fisheries, vol. 39, pp. 141-201, 60 figs. Notes on food of eight species; it is chiefly crustaceans, next in order coming worms and fishes. Bibliography. *Cynoscion regalis:* Shrimps, schizopods, isopods, amphipods, worms when small, fish when mature, but including shrimps and squids; *Bairdiella chrysura:* Schizopods, isopods, amphipods, worms, fish; *Stellifer lanceolatus:* Schizopods, copepods, decapods, ostracods, amphipods, worms; *Leiostomus xanthurus:* Ostracods, copepods, amphipods, worms, mollusks; *Micropogon undulatus:* Shrimps, echinoderms, worms, mollusks, copepods, ostracods, amphipods; *Menticirrhus americanus:* Crabs, shrimps, worms, fish; *Menticirrhus saxatilis:* Shrimps, amphipods, schizopods, worms, fish; *Pogonias cromis:* Mollusks including oysters; *Eques pulcher:* Small crustaceans.

Wickliff, Edward L.

1920. Food of young small-mouth black bass in Lake Erie. Proc. Amer. Fisheries Soc., pp. 364-371. Report on 313 specimens, the most important items being copepods found in 61 per cent of the stomachs and Cladocera in 39 per cent. Other commonly taken foods were midge larvae and pupae, adult insects, fish, and mayfly nymphs.

AMPHIBIA

Drake, Carl J.

1914. The food of *Rana pipiens* Schreber. Ohio Naturalist, vol. 14, no. 5, pp. 257-269, Mar. Detailed account of the contents of 209 stomachs collected at Cedar Point, Ohio.

Frost, S. W.

1924. Frogs as insect collectors. Journ. New York Ent. Soc., vol. 32, no. 4, pp. 174-185, pl. 14, Dec. Eat worms, snails, crayfishes, spiders, mites, insects and frogs; insects most important. Larvae: Lepidoptera 9; Coleoptera 24; Diptera 13; Neuroptera 1. Adults: Orthoptera 1; Hemiptera 25; Neuroptera 3; Mecaptera 1; Diptera 33; Coleoptera 242; spiders 37; pseudoscorpions 1.

Garman, H.

1901. The food of the toad. Bull. 91, Kentucky Agr. Exp. Sta., pp. 60-68, fig. 16. Report on 20 stomach contents.

Hamilton, W. J., Jr.

1930. Notes on the food of the American toad. Copeia, 1930, no. 2, June 30, p. 45. *Bufo americanus.* Report on food of 400 young toads: Diptera 22 per cent, mostly larvae; mites 15.5 per cent; ants 12.8; beetles and their larvae 11.8, the most abundant group being Staphylinidae; thrips 10.1; Collembola 6.2; Lepidoptera, Hymenoptera, aphids, sowbugs, spiders, worms, and snails, the remainder.

Kirkland, A. H.

1904. Usefulness of the American toad. Farmers' Bull. no. 196, U. S. Dep. Agr., 16 pp. Contents of 149 stomachs discussed.

Klugh, A. Brooker.

1922. The economic value of the leopard frog. Copeia, no. 103, pp. 14-15, Feb. 15. Contents of 25 stomachs; chiefly *Melanoplus femur-rubrum* and *Leptinotarsa 10-lineata.*

Munz, Philip A.

1920. A study of the food habits of the Ithacan species of *Anura* during transformation. Pomona Coll. Journ. Ent. Zool., vol. 12, no. 2, pp. 33-56, June. Report on 586 stomachs of eight species; summaries of results of previous investigators.

Smallwood, W. M.

1928. Notes on the food of some Onondaga Urodela. Copeia, no. 169, pp. 89-98, Oct. 25. *Ambystoma maculatum:* Centipeds, earthworms, snails, sowbugs, crickets, grasshoppers, beetles; *Plethodon cinereus:* Centipeds, earthworms, snails, sowbugs, ants, beetles, mites, spiders, phalangids, caterpillars, grasshoppers, flies springtails; *Eurycea bislineata:* Earthworms, caterpillars, and beetle, fly, and caddisfly larvae; *Triturus viridescens:* Snails, waterboatmen, fish, earthworms, beetle larvae; bivalves, daphnia, cater-

pillars, amphibian eggs (including its own), water bugs, mosquito and other fly larvae, slugs, snails, leeches, spiders, springtails, beetles, mites.

SURFACE, H. A., [ED.]

1913. First report on the economic features of the amphibians of Pennsylvania. Zool. Bull. Div. Zool. Pennsylvania Dep. Agr., vol. 3, nos. 3-4, pp. 67-152, figs. 1-25, pls. 1-11, May-July. General discussion of the subject, including report on examination of stomachs of 14 species of salamanders, two of toads, and nine of frogs.

WRIGHT, A. H.

1920. Frogs: Their natural history and utilization. App. 6, Rep. U. S. Comm. Fisheries 1919, 44 pp. Notes on the food of various species, pp. 38-42. Enemies, pp. 42-44; invertebrates, fishes, amphibians, reptiles, birds, and mammals discussed.

WRIGHT, A. H., AND HABER, JULIA M.

1922. The carnivorous habits of the purple salamander. Copeia, no. 105, pp. 31-32, April 15. Feed on aquatic insects; in captivity take frogs and salamanders.

REPTILIA

BURT, CHAS. E.

1928. Insect food of Kansas lizards with notes on feeding habits. Journ. Kansas Ent. Soc., vol. 1, no. 3, pp. 50-68, July. Notes on stomach contents of seven species with compiled information on others. Of the total food in all lizard stomachs examined 51.92 per cent was Orthoptera, 11.65 Lepidoptera, 9.35 Arachnida, 8.90 Hymenoptera, and 6.00 Coleoptera; Diptera, Hemiptera, Trichoptera, and Mollusca in smaller amounts.

KELLOGG, REMINGTON.

1929. The habits and economic importance of alligators. Techn. Bull. 147, U. S. Dep. Agr., 36 pp., 2 pls., Dec. Food (pp. 21-32), nearly half is crabs, crawfishes, and shrimps; spiders, insects of various orders, toads, smaller alligators, lizards, turtles, snakes, birds and mammals also eaten.

LYDEKKER, R.; CUNNINGHAM, J. T.; BOULENGER, G. A.; AND THOMSON, J. A.

1912. Food and growth [of reptiles], reptiles, Amphibia, fishes, and lower Chordata, pp. 47-61, London. "The food of reptiles is very various," a dictum which shows distribution of predation is as characteristic of this phylum as of others. Details in many cases.

PACK, H. J.

1921. Food habits of *Sceloporus graciosus graciosus* (Baird and Girard). Proc. Biol. Soc. Washington, vol. 34, pp. 63-66, Mar. Report on the contents of 71 stomachs.

1922. Food habits of *Crotaphytus wislizenii* Baird and Girard. Proc. Biol. Soc. Washington, vol. 35, pp. 1-3, Mar. 20. Report on the contents of 18 stomachs.

1923. Food habits of *Callisaurus ventralis ventralis* (Hallowell). Proc. Biol. Soc. Washington, vol. 36, pp. 79-81, Mar. Twenty stomachs: disclosing caterpillars, coccinellids, meloids, crotylids, chrysomelids, weevils, grasshoppers, mantids, Hemiptera, ant-lions, Diptera, and spiders.

1923. Food habits of *Crotaphytus collaris baileyi* (Stejneger). Proc. Biol. Soc. Washington vol. 36, pp. 83-84, Mar. Report on 16 stomach examinations; Orthoptera the principal animal food, caterpillars, wasps, bugs, leaf-hoppers, and ant-lions also being taken.

1923. The food habits of *Cnemidophorus tessellatus tessellatus* (Say). Proc. Biol. Soc. Washington, vol. 36, pp. 85-89, Mar. Sixty-three stomachs containing caterpillars, 37.7 per cent of the food, grasshoppers 14.4; beetles 14.2; other insects 14.27; and arachnids 8.2.

SURFACE, H. A. [ED.]

1906. The serpents of Pennsylvania. Monthly Bull. Div. Zool. Pennsylvania Dep. Agr., vol. 4, nos. 4-5, pp. 115-202, pls. 14-52, figs. 5-23, Aug.-Sept. Includes data on contents of stomachs of snakes of 14 species.

1907. The lizards of Pennsylvania. Bull. Div. Zool. Pennsylvania Dep. Agr., vol. 5, no. 8, pp. 235-258, pls. 30-33, figs. 26-28, Dec. 1. Notes on food of five species, in the case of two of them based on examinations of stomachs.

1908. First report on the economic features of turtles of Pennsylvania. Bull. Div. Zool. Pennsylvania Dep. Agr., vol. 6, nos. 4-5, pp. 107-195, pls. 4-12, 16 figs., Aug.-Sept. Includes report on stomach contents of representatives of nine species.

WINTON, W. M.

1915. A preliminary note on the food habits and distribution of the Texas horned lizards. Science, n. s., vol. 41, pp. 797-8, May 28. Brief summary of the results of examination of 485 stomachs; agricultural ants found in 80 per cent and stink bugs in 60 per cent of the stomachs.

WRIGHT, A. H.; FUNKHOUSER, W. D.; AND BISHOP, S. C.

1915. A biological reconnaissance of the Okefinokee Swamp in Georgia. Turtles, lizards, and alligators, by Wright and Funkhouser, pp. 108-139; snakes by Wright and Bishop, pp. 130-192. Proc. Acad. Nat. Sci. Philadelphia, pp. 107-192, pls. I-III, figs. 1-14, Mar. (Apr.). Notes on food of many of the species.

AVES

The entries under food of birds are chiefly general papers in which bibliographies introductory to the very extensive literature of the subject can be found.

CLELAND, J. B.

1922. The parasites of Australian birds. Trans. and Proc. Roy. Soc. South Australia, vol. 46, pp. 85-118. Cestodes in 86 species, adult nematodes in 28, Microfilaria in 34, Acanthocephala in 25, trematodes in 38, fleas on 3, Hippoboscidae on 4, Mallophaga on 107, ticks on 4, mites on 38, Haemosporidia in 47, and haemoflagellates in 12.

CRAM, ELOISE B.

1927. Bird parasites of the nematode suborders Strongylata, Ascaridata, and Spirurata. U. S. Nat. Mus. Bull. 140, 465 pp., 444 figs. About 500 species.

FORBUSH, E. H.

1904. Special report on the decrease of certain birds, and its causes with suggestions for bird protection. 52nd Ann. Rep. Massachusetts State Board Agr., pp. 429-543, 2 pls. Chief causes, gunners, trappers, egg collectors, destruction of environment, natural enemies, and the elements.

1907. Useful birds and their protection. Massachusetts State Board Agr., 437 pp., 56 pls., 171 figs. Capacity of birds for destroying pests, birds as enemies of insects, and mammals, hairy caterpillars, plant lice, also on natural checks upon bird life.

1916. The natural enemies of birds. Econ. Biol. Bull. 3, Massachusetts State Board Agr., 58 pp., 7 pls., figs. A thorough review of the subject, treating enemies among domesticated animals and among wild mammals, birds, reptiles, amphibians, fishes, and insects.

GROSS, A. O.

1928. The heath hen, pp. 525-526. Marsh hawk, Cooper's hawk, sharp-shinned hawk, and goshawk, the snowy owl, and crows enemies of this species. Domestic cat the worst.

HENDERSON, JUNIUS.

1927. The practical value of birds, 342 pp. An exhaustive review of literature on the economics of American birds, with a long bibliography. Chapters on birds as enemies of injurious insects, mammals, and plants; birds as scavengers, and on the destruction of birds.

HERSEY, L. J.

1907. A naturalist's notes on birds and snakes. Outdoor Life, pp. 481-483, Nov. Snakes eating birds and their eggs.

LEWIS, ELISHA J.

1857. [Enemies of the partridge]. The American sportsman, 3rd ed., Enemies of the partridge (pp. 102-4): fox raccoon, weasel, polecat, serpent, hawk, crow (p. 102); sparrow hawk, pigeon hawk, goshawk (p. 103).

1857. [Enemies of the wild turkey]. The American sportsman, 3rd ed. Wolf, fox, lynx, cougar, opossum, and wild cat. Also the larger hawks and owls (p. 141).

1857. [Enemies of the ruffed grouse]. The American sportsman, 3rd ed. Polecats, weasels, raccoons, opossums, foxes, crows, larger hawks (p. 150).

LINTON, E.

1927. Notes on cestode parasites of birds. Proc. U. S. Nat. Mus., vol. 70, art. 7, 73 pp. 15 pls. Thirty-four species.

1928. Notes on trematode parasites of birds. Proc. U. S. Nat. Mus., vol. 73, 36 pp., 11 pls. Twenty-two species.

LONGSTAFF, T. G.

1927. Bird's-nesting mice and insects. British birds, vol. 20, pp. 198-199. Notes certain insects (*e. g.* ants) attacking nestlings, and mice destroying eggs.

MCATEE, W. L.

1913. Index to papers relating to the food of birds by members of the Biological Survey in publications of the United States Department of Agriculture, 1885-1911. U. S. Biol. Surv. Bull. 43, 1913, 69 pp. Bibliography with subject index.

PLATH, O. E.

1919. Parasitism of nestling birds by fly larvae. The Condor, vol. 21, pp. 30-38. *Protocalliphora azurea* in 30 out of 63 nests; parasites and scavengers on this dipteron.

RANSOM, B. H.

1909. The taenioid cestodes of North American birds. U. S. Nat. Mus. Bull. 69, 141 pp., 42 figs. About 140 species; bibliography.

RUSSEL, J. F.

1926. Predatory bass. Outdoor Life, vol. 57, no. 2, pp. 146-147, Feb. Black bass with swallow in its stomach. San Diego Co., Calif.

TUCKER, B. W.

1926. Bird's-nesting bank voles. British birds, vol. 20, pp. 158-160. Evidence was given that bank voles destroy birds' eggs. This note was followed by a number of other communications by various authors, in the same journal (vol. 20, pp. 180-181, 198-199, 207, 230, 255), which showed that various species of mice commonly attack birds' eggs.

WEED, C. M., AND DEARBORN, NED.

1903. Birds in their relations to man, 380 pp., illus. Extensive chronological bibliography; chapters on birds as regulators of outbreaks of injurious animals, relations of birds to predacious and parasitic insects.

WILD, O. H.

1927. Wasps destroying young birds. British birds, vol. 20, pp. 254-255.

MAMMALIA

BABCOCK, H. L.

1914. Some observations on the food habits of the short-tailed shrew (*Blarina brevicauda*). Science, n. s., vol. 40, pp. 526-530, Oct. 9. Review of literature, chiefly about observations on captive animals.

BAILEY, VERNON, AND SPERRY, CHAS. C.

1929. Life history and habits of grasshopper mice, genus *Onychomys*. Techn. Bull. 145, U. S. Dep. Agr., 19 pp., 4 pls., Nov. Animal food (pp. 10-19), nearly 90 per cent of the whole, largely grasshoppers, crickets, caterpillars, moths, and beetles; insects of other orders, spiders, and mice also taken.

BROOKS, FRED E.

1908. Notes on the habits of mice, moles, and shrews. Bull. 113, West Virginia Agr. Exp. Sta., pp. 89-133, 10 pls., 2 figs., Jan. Considerable on food; review of previous writings.

BRUCE, JAY.

1925. The problem of mountain lion control in California. California Fish and Game, vol. 2, no. 1, pp. 1-17, figs. 1-5, Jan. Each mountain-lion costs the State $1,000 a year in deer meat, or about $15,000 to maintain the animal during its natural existence.

CRIDDLE, NORMAN.

1917. Varying hares of the prairie provinces. Agr. Gaz. Canada, vol. 4, no. 4, p. 262, Apr. Goshawk, golden and bald eagles, and great horned owls serious enemies.

Dixon, Joseph.

1925. Food predilections of predatory and fur-bearing mammals. Journ. Mamm., vol. 6, no. 1, pp. 34-46, pl. 4, Feb. Wild cat: Mammals, birds, fish; coyote: Game, stock, rodents, insects, mammals, birds; mountain-lion: Deer, stock, small wild mammals; skunks: Insects, rodents, birds, mammals.

Dyche, L. L.

1903. Food habits of the common garden mole (*Scalops aquaticus machrinus* Rafinesque). Trans. Acad. Sci. Kansas 1901-1902, pp. 183-186. Report on the stomach contents of 50 specimens.

Forbush, E. H.

1916. The domestic cat. Bird killer, mouser, and destroyer of wild life. Means of utilizing and controlling it. Econ. Biol. Bull. 2, Massachusetts State Board Agr., 112 pp., 20 pls., figs. The most comprehensive review of the subject; cats kill millions of birds annually; destructive also to moles, shrews, toads, field mice, wood mice, insects.

Garman, H.

1895. The food of the common mole. 7th Ann. Rep. Kentucky Agr. Exp. Sta. 1894, pp. xli-xlv. Notes on contents of 14 stomachs.

Hamilton, W. J., Jr.

1930. The food of the Soricidae. Journ. Mamm., vol. 11, no. 1, pp. 26-39, Feb. Over 300 stomachs representing four species; food is insects, annelids, Crustacea, snails, mice, salamanders, arachnids, centipeds, and millipeds. Bibliography.

Johansen, Frits.

1910. Observations on seals (Pinnipedia) and whales (Cetaceae) made on the "Danmark Expedition" 1906-1908. Danmark Eksp. Grönl. Nordöstkyst, 1906-1908, vol. 5, no. 2, pp. 203-224, 9 figs. Includes some notes on food.

Johnson, Chas. E.

1925. The muskrat in New York; its natural history and economics. Roosevelt Wild Life Bull., vol. 3, no. 2, pp. 205-320, pl. 5, figs. 48-87, Mar. Animal food includes bivalves, snails, crayfish, insects, fishes, turtles, and birds; enemies include minks, foxes, weasels, otters, hawks, and owls.

Lantz, D. E.

1905. Kansas mammals in their relations to agriculture. Bull. 129, Kansas Agr. Exp. Sta., Dec., 1904, pp. 331-404, 1 pl., 1 fig. Notes on the food habits of most of the groups.

1906. Meadow mice in relation to agriculture and horticulture. U. S. Dep. Agr. Yearbook 1905, pp. 363-376, pls. 38-41, fig. 89. Natural enemies (pp. 370-373) include wolves, lynxes, foxes, badgers, raccoons, opossums, skunks, minks, weasels, shrews, hawks, owls, crows, shrikes, cranes, herons, bitterns, snakes, and domestic cats and dogs.

1918. The house rat the most destructive animal in the world. U. S. Dep. Agr. Yearbook 1917, pp. 235-251, pls. 41-44. Natural enemies (pp. 248-249) include domestic dog, cat, and ferret, as well as snakes, storks, herons, owls, hawks, skunks, weasels.

1923. Economic value of North American skunks. Farmers' Bull. 587, U. S. Dep. Agr., 24 pp., 10 figs. Food (pp. 9-14), poultry, game, mice, and armyworms, tobacco worms, whitegrubs, hop grubs, grasshoppers, potato beetles and other insects.

L.[UCAS], F. A.

1905. The Newfoundland whale fisheries. Science, n. s., vol. 21, p. 713. May 5. Large whales feed almost exclusively on *Euphausia;* finbacks upon caplin.

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1909. Mouse plagues, their control and prevention. U. S. Dep. Agr. Yearbook 1908, pp. 301-310, pls. 21-25. During a plague near Humboldt Lake, Nevada, 2,000 predatory birds and 1,000 mammals put in their appearance and together consumed about 1,350,000 mice per month.

1928. The mouse infestation of Buena Vista Lake Basin, Kern County, California, September, 1926, to February, 1927. Monthly Bull. California Dep. Agr., vol. 17, no. 10, pp. 538-560, figs. 91-102, Oct. Ring-billed gulls, short-eared owls, barn owls, various hawks, ravens, great blue herons, road-runners, shrikes, coyotes, skunks, and house cats noted as predators (pp. 550-552).

RAINBOW, W. J.

1913. Food, medicines, and charms of savage man. Abstract in Rep. Trustees Australian Mus. 1913, p. 9. Humans feeding on spiders, beetle larvae, caterpillars, grasshoppers, ants, bees, wasps, termites, and scorpions.

SCHEFFER, THEO. H.

1910. The common mole. Bull. 168, Kansas Agr. Exp. Sta., 30 pp., figs. Natural enemies (pp. 20-21) include hawks, owls, coyotes, domestic dogs. On the whole has few foes.

1927. American moles as agricultural pests and as fur producers. Farmers' Bull. 1247, U. S. Dep. Agr., 20 pp., 18 figs. Animal food (pp. 7-8), earthworms, beetles and their larvae, spiders, centipeds, ants, caterpillars.

WEST, JAMES A.

1910. A study of the food of moles in Illinois. Bull. Illinois State Lab. Nat. Hist., vol. 9, pp. 14-22, Oct. Details of contents of 56 stomachs; references to previous literature.