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A DETERMINATION OF THE ECONOMIC STATUS OF THE WESTERN MEADOW-LARK (*STURNELLA NEGLECTA*) IN CALIFORNIA

BY

HAROLD CHILD BRYANT

A Thesis presented to the Faculty of the College of Natural Sciences of the University of California in partial fulfillment of the requirments for the Degree of Doctor of Philosophy. May, 1913.

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PREFACE

The impetus given in late years to the study of the relations of birds to agriculture in the United States is traceable to the extensive work of the United States Bureau of Biological Survey. From the organization of this department of the United States Department of Agriculture, July, 1885, to December 31, 1911, members of the Biological Survey have prepared and published one hundred and thirty-one documents relating wholly or in part to the food of birds. Notes on the economic status of over four hundred species of native birds and of over fifty species of foreign birds are to be found in these publications. In many cases extended studies have been made of the food of birds by the examination of stomach contents. In no other country has economic ornithology been accorded the attention it has received at the hands of the United States Department of Agriculture.

In a newly settled state like California, where large tracts of land are being brought under cultivation, disturbances of the natural order of bird life arise in two ways. First, the natural food supply of birds is destroyed through cultivation. Second, a new source of food is often supplied by cultivated crops. Hence birds become of great economic importance. The variety of conditions to be found in so large a state as California makes a study of these economic relations of birds complex and difficult. In spite of the need, therefore, of a knowledge of the value of birds, comparatively little work along this line has been done in this state. Until recently two bulletins entitled "Birds of California in Relation to the Fruit Industry," by F. E. L. Beal, published by the U. S. Bureau of Biological Survey, and a few scattered notes in ornithological literature afforded the only published material on the economic relations of birds in California.

Complaints of the depredations of birds in this state have been numerous. The injury to fruit caused by the linnet (*Carpodacus mexicanus frontalis*) is so great that this bird is branded as a pest by the fruit-grower. In recent years grain-growers have complained of damage to sprouting grain caused by western meadowlarks (*Sturnella neglecta*). These birds have been accused, and rightly so, of boring down beside the sprout with their long bills and pulling off the kernel of grain. Ranchers have maintained that in some cases whole fields of grain have had to be reseeded because of the loss occasioned by these birds. In fact, there has developed so much sentiment against the meadowlark that there has been a persistent attempt made at each legislative session to take protection from the bird.

As the western meadowlark is a bird defended by many because of its insectivorous habits, the agitation following the complaints has afforded an exceptional opportunity to determine scientifically the economic value of this bird by a thorough investigation. Such an investigation has been made possible through the patronage of the California State Fish and Game Commission, which established a research fellowship in the Department of Zoology of the University of California. In January, 1911, I was appointed Fellow in Applied Zoology on the Fish and Game Commission Foundation in the University of California, with instructions to carry on an investigation into the relation of certain California birds to agriculture. The commission assumed the expense and through its deputies furnished the material for stomach examination. The office work and the laboratory work have been carried on in the Zoological Department of the University of California. The investigation has, therefore, been conducted through the co-operation of the State Fish and Game Commission with the University of California.

To the men past and present who have preceded me in this line of work and who have furnished the world with the underlying facts which have established the science of economic ornithology I wish to give due credit, for without their contributions this work must necessarily have been far more elemental. The helpful criticisms and valuable suggestions of Professor Charles A. Kofoid of the University of California, under whose direction the work has been done, have inspired and assisted me in the task. To Dr. Joseph Grinnell, Director of the Museum of Vertebrate Zoology in the University of California, who has often given me of his time to discuss certain features of the work, I owe much. The help also of Mr. E. R. Ong as laboratory assistant, and of Professor C. W. Woodworth, Dr. E. C. Van Dyke, Dr. F. E. Blaisdell, Mr. John Bridwell, Mr. W. L. McAtee, Miss Anna M. Lute and others in the identification of insects and weed seeds has lightened the burden and facilitated this part of the investigation.

Although collections have been made of a number of birds about which complaint has been received (western robin, bicolored red-wing, Brewer blackbird, horned lark, western mourning dove, and roadrunner), yet, because it was the special object of attack, effort has been concentrated on determining the economic status of the western meadowlark.

The investigation has consisted primarily of field investigation, experimentation, and stomach examination. A large part of the field work has been carried on at Lathrop, San Joaquin County, California, a place admirably suited for the work in hand. Duties on the agricultural and horticultural demonstration train, which toured the state in 1911 and 1912 under the auspices of the Department of Agriculture of the University of California and the Southern Pacific Railway Company, have afforded additional opportunity to study conditions from one end of the state to the other.

Economic ornithology is a new science and has hardly progressed further than the stage of preliminary interest and study. As a result practically all of the work attempted thus far has been of the extensive rather than of the intensive sort, and has been made up largely of a study of the food of birds. In this investigation the attempt has been made to improve on past methods and, by determining the food of birds taken in the same locality each month, or twice each month, to furnish reliable evidence as to their food throughout the whole year. A study of the bird in the field, its depredations, and its life-history, has also been made in order that all available evidence might be obtained.

Considerable difficulty has been experienced in that there has been, and now is, a difference of opinion as to the criteria to be used in the determination of the economic status of a bird. The ideas which have been advanced in the past, and even those of the present day, appear to be unsatisfactory, or at least untrustworthy. It seemed, therefore, that a review of past methods, with the addition of such new ones as appeared to be valuable, might prove not only interesting but of considerable value to future workers in the field. A similar lack of information regarding methods of stomach examination has been evident. A detailed account of the method used in this investigation, therefore, seems justified.

The service which birds render to agriculture has doubtless been overemphasized. On the other hand, the position taken by some that birds are of no value as insect and weed-seed destroyers hardly seems justified by the facts. If there be a misconception as to the utility of birds, it is high time we sought to destroy it and to establish truth in its stead.

The economic relations of birds must necessarily become more and more important. As they do so, the extensive study of the past few years will give way to the intensive study necessary to solve the greater problems of the future. Probably no one thing will play a greater part in the conservation of wild life than will this intensive study. Recognition of the economic value of a single bird will stimulate interest in the protection of all.

This work is published, therefore, in the hope not only that the facts and data here presented may be of general interest and of value to future workers in economic ornithology, but that it may be a factor in promoting the conservation of wild life in California, a state which still possesses enough of its original fauna to make its conservation important and eminently desirable.

INTRODUCTION

Doubtless if our knowledge were not so limited we might be able to find a use for most living things. As it is, we designate animals as useful, neutral, or injurious because of their effect on ourselves or our interests. A thorough study of the interrelations of such animals often reverses our original decisions regarding them. Not many years ago insects as a class were called injurious because some of them destroyed certain crops. Today only a part of the insects are considered destructive, and we are yearly finding that others are of neutral or beneficial character.

Not many years ago birds were looked upon either as pests or as marks for the gunner. Today most of them are looked upon as valuable assets of the agriculturist. As science in the past has slowly lifted us to a plane where we study the complex interrelations instead of the single and obvious ones, so in the future we may expect that more and more each form of life will be found to fill a particular niche in its environment better than any contiguous form.

And yet, viewed from the utilitarian standpoint, there is a certain value in classifying organisms as injurious or beneficial. The danger lies not in the classification itself, but in the risk attendant upon a judgment hastily made or one based on circumstantial or partial evidence. Being the dominant form of life on the earth, it is only natural that we measure the usefulness of things by their immediate effect on ourselves or our interests rather than on the whole complex of nature.

An intimate knowledge of the use of wild life is indispensable to sane conservation. Anything known to be useful may justly demand protection. Anything known to be of no utility in nature may justly be accorded destruction. Ignorance has caused the waste characteristic of the past. Knowledge must prevent waste in the future.

What may not seem to be of use today may be of great importance tomorrow. It appears that the economic value of wild life seldom becomes evident until the form becomes extinct, or at least diminished in numbers. It was only a few years ago that fish were so abundant that no attention whatever was paid to their life-histories. Today the study of ichthyology, including fish-hatching, is a necessity, in order that the supply of this kind of food may continue to be available. Not many years ago people believed that there was an inexhaustible supply of game. Today strict game laws and the most careful conservation alone prevent the extinction of many forms.

Fifty years ago the farmer in the east may have lost some grain and corn from the depredations of birds, but he either planted an extra acre or two to make up for the loss or took it as a matter of course. At the present time, however, when we find not only much of the available land under cultivation, but even that cut up into small tracts and men attempting to earn a living on ten or twenty acres instead of on eighty or a hundred, the depredations of birds are more noticeable. The loss of a sack of grain is hardly noticeable in a large field, but let the same amount be lost in a two- or three-acre field and the loss becomes relatively important and very apparent. It is only natural, therefore, that at the present time complaints against birds are more frequent and more insistent.

Depredations probably increase also as the natural food supply of birds is destroyed and they have to rely on the products of civilization. The change of food caused by change in environment sometimes causes an increase in the number of birds of a species, and thus increases the extent of the depredations. Apparently there are a number of birds in California which have directly profited by the change of environment and are increasing in numbers. The linnet, western meadowlark, and mockingbird undoubtedly belong to this class.

As the crops change, and consequently the food supply, we may even expect that in the future the food habits of birds will change. Hence a knowledge of the food habits of birds at the present time may be of far greater value in the future, when such data are needed for comparison.

Whether it is best to destroy certain birds because of their depredations, or to preserve them because of their value as insect or weed-seed destroyers, has become a real problem. There is not a farmer who is not at some time of the year confronted with this problem. In a newly settled country the question as to the value of certain birds is often of grave importance. If nature were not so closely woven together we might easily solve the problem by simply exterminating those birds which cause damage. In the early days this was tried. It is experience that has taught us the danger attendant on the indiscriminate extermination of any form of life.

The problem stated, the next thing to be considered is: How shall it be solved? Observation has proved an unsafe method of determining the true value of a bird. Mere sentiment fails to convince a large number of the class of people deeply interested from actual contact with the problem. The method which has proved the most dependable is a thorough scientific investigation. The problem is complex. It involves a knowledge of the life-history of birds, insects, and plants, a conception of the interaction of organisms, and an appreciation of the accompanying ecological relations.

A scientific investigation as a means of determining the status of a bird presents just as great possibilities as this method has in other fields. In preventive medicine we see the results of scientific method. The efficiency of the forest service can be attributed to the same methods. If, then, this type of investigation can help us to conserve our health and our forests, it should also lead to the best method of conserving our native birds.

Professor Charles S. Minot has defined the method of science as "the art of making durable, trustworthy records of natural phenomena." He goes on to say: "The method of science is not special or peculiar to it, but only a perfected application of our human resources of observation and reflection—to use the words of von Baer, the great embryologist. To secure reliability the method of science is, first, to record, everything with which it deals, the phenomena themselves and the inferences of the individual investigators, and to record both truly; second, to verify and correlate the personal knowledges until they acquire impersonal validity, which means, in other words, that the conclusions approximate so closely to the absolute truth that we can be safely guided by them." These statements justify the use of scientific method for any modern problem and especially for the problem in hand.

"But putting aside economic and utilitarian considerations, there is to some of us a greater stimulus to solve the problems of nature. With the birds, and the insects and plants upon which they feed, we share a common heritage, and the more we learn of the life of these, our fellow-workers, the nearer we approach solution of the great riddle of the Universe, the mysterious law-abiding scheme of Nature. The book of knowledge to which we add some iota is marred with mystery, superstition and error, but each proved fact cleanses its pages. 'Facts,' says Laing, 'are the spokes of the ladder by which we climb from earth to heaven.' " (See Coward, 1912.)

The labor, time and cost of such an investigation as this is amply justified by the results to be expected. A knowledge of the real economic status of a bird means dollars in the pocket of the rancher, for the destruction of any bird which causes serious damage, or the preservation of any bird that is a benefit, has a direct bearing on the size of the crop raised. Nor is the value to the rancher the only value to be considered, for, as will be seen, a bird has a certain value to society that cannot be reckoned in dollars and cents.

Some entomologists, seeing in insecticides the only successful control measure against insects, are inclined to minimize the value of such a natural control as birds. True it is that birds apparently do not prevent or entirely control insect outbreaks. for insects continue to ravage crops, no matter what the bird population. However, if a certain number of insects cause a certain amount of damage, it must follow that a diminution of the number of insects causing damage must cause some diminution of the damage done even if it be not proportional. We are justified in saying, therefore, that the fact that birds destroy great numbers of injurious insects shows them to be important agents in contributing to the safety not only of crops, but of all vegetation. Judging from the great numbers of insects destroyed at the time of an insect outbreak, we can safely infer that birds may be instrumental in preventing the appearance of insects in abnormal numbers, by helping to keep the numbers near the normal, which we approximate by the phrase, "the balance of nature."

In this practical age almost everything is viewed from the standpoint of dollars and cents. Hence it is desirable that we study the economic value of birds. There is danger, however, in so doing, for such studies may tend to minimize to a certain degree a value which cannot be expressed in dollars and cents. To say that a meadowlark is worth so many dollars to the rancher each year may obscure its esthetic value.

The strongest opponents of the theory that birds are beneficial often emphasize the esthetic value. The following is a quotation from one of these opponents (Baskett, 1910): "Make their song, beauty, grace and interesting habits a part of our culture—and their preservation part of our ethics, but do not try to foist them on the farmer as an economic asset, for he knows better in many cases. If the soldier can make better marches under the martial influence of the 'spirit-stirring drum' and 'ear-piercing fife,' so can the farmer gather inspiration from the activity and cheerfulness of birds."

One need only point to the place which birds take in art and literature to prove their esthetic value. The inspiration for some of the finest paintings, poems and other pieces of literature has come from a knowledge of bird life. That exhilaration and inward joy awakened with an acquaintanceship with birds has a real value. What mental pictures stay longer with us than do those gained first hand from nature? Those things which make the world more beautiful make it more fit to live in.

Few birds there are that have a greater esthetic value than does the western meadowlark. One reason for this is that it is a conspicuous bird and therefore known to every one. Its song has been pronounced far sweeter than that of its eastern relative. Its plumage and general habits add to its attractiveness. A bird associated with the fields and plains, it adds great interest to the general loneliness and monotony of our great treeless areas. What person traveling along a lonely country road has not been cheered by the bird which stands bobbing on many a fence post and telegraph pole and continually pours forth its ''Eh heu wheel'iky, wheel'iky, wheel'iky''? (For the musical notation of the song of the western meadowlark see Allen, 1881.)

The educational value of birds has more utilitarian aspects. Birds teach a code of ethics exceeded only by that of man himself. The fidelity of parents to each other and to their helpless young and the industry, cleanliness, grace, and cheerfulness exemplified by them add much to the finer ideals of life.

The educational and esthetic points of view can even be considered economically. To many, this type of presentation detracts instead of adds. Nevertheless, it is true that the esthetic and educational value of birds has its economic relations. Many a summer resort is chosen because of the abundance of birds in the vicinity, and many a summer vacationist is influenced in his choice of destination by the presence of birds in the vicinity. The value of suburban property is enhanced by the presence of birds. That many a business man has been attracted to certain suburban localities because of the presence of the meadowlark and its song is self-evident.

Carrying this point of view to an extreme has often antagonized certain classes, and herein lies a danger. Yet the facts here presented can easily be verified. A determination of the status of a bird must include a study of the bird from every point of view. To many city folk the esthetic and educational value of a bird is the more important, for they never see it from any other point of view. Perhaps the rancher is an extremist on one side and the city resident on the other. A modification of the views on both sides is very desirable to a sane appreciation of the value of birds in general and the western meadowlark in particular.

The advance made in investigations of the economic relations of birds since Professor Aughey (1878) studied the relation of birds to the locust ravages in Nebraska up to the present, when government experts give the whole of their time to such inquiries, demonstrates the growth of the science of economic ornithology.

A study of this advance, however, shows that only a beginning has been made. Although we know in general the food habits of our common birds, yet conditions vary so greatly that we cannot definitely predict the food in any given locality. The work thus far has afforded us a general survey of the food habits of birds and in some few instances has given us definite knowledge as to the usual food of certain birds. The thing that economic ornithology has not afforded us as yet is a *detailed study of the food of a particular bird in a given locality throughout the whole year.*

The importance, then, of a thorough knowledge of the economic relations of a bird in addition to its life-history is evident. It has been left to one of the new sciences, economic ornithology, to tell us of these economic relations and to explain the real status of birds. The agitation coincident with the establishment of this science had made known at least five facts:

1. Birds are very largely insectivorous, and as a result are important in keeping the numbers of insects in check.

2. The amount of food required by birds is enormous.

3. Birds often considered injurious are really beneficial, and vice versa.

4. Birds change their food habits and feed on the kind of food most easily obtained.

5. Birds are very important in preserving that balance of nature most suited to the interests of man, and their place cannot be filled by any other class of living things.

These facts are now familiar. They have furnished a basis for a sane protection, have demonstrated the intricacy of the interactions of organisms, and have helped develop the economic view of birds.

Although economic ornithology is fundamentally the study of birds from the standpoint of dollars and cents, and, therefore, includes their use as food, as cage birds, etc., yet emphasis has rightly been placed on the study of the food of birds. As a result, economic ornithology is most often used in a restricted sense and has reference to the study of the food of birds. Great activity is evidenced in this line of work at the present. Not a month passes that there is not some important contribution to economic ornithology, and there is scarcely an entomological report that does not mention the value of birds as insect destroyers. To appreciate the work of the present, however, there must needs be some knowledge of the work of the past. A brief historical review of the subject, with emphasis on the methods used, will furnish this needed information.

HISTORY OF METHODS IN ECONOMIC ORNITHOLOGY

We need only to examine in detail the progress of our sciences to be convinced that there is such a thing as evolution. As we interpret their progress step by step, and thus survey their general trend, it would seem that the development has been of the orthogenetic type. The biological sciences have been a little slower than others in their development, but they are now taking front rank. One of the most marked tendencies to be noted in history is that of a change from the period when biologists drew conclusions from facts gained from observation only to the present period when more intensive study and experimental evidence are demanded.

The period of time previous to 1850 may be termed the primitive period, for during this time we find only an occasional mention of the food habits of birds, the entire time of the workers in this field having been given over to classification and habit notes. The following period (1850–1865) marks the time when the specialized science of economic ornithology was founded. It was a period of interest and agitation. Before the conclusion of this period the modern methods of investigation were introduced into America by Jenks (1860). The period since 1865 is best considered the modern period—a time when the attempt to reach truth is backed by experimental evidence and the work becomes intensive rather than general. (See Locy, 1908.)

To the first period belong such men as Catesby, Edwards, Forster, Latham, Bartram, Hearne, and Barton—men who took an active interest in natural history and enriched ornithological literature with what observational facts they were able to glean. In the latter part of this first epoch there began a marked tendency to gain more than superficial facts by observation, and so in the writings of Wilson, Audubon, and Baird we find mention of the food of birds. (See Palmer, 1899.)

It was not till 1860 that Jenks (1860) applied scientific method to the study of the food of birds. Previous to this time there had been considerable agitation concerning the value of birds, and many papers dealing with the question appeared in agricultural journals. Le Baron's "Observations of the Birds of Illinois Interesting to the Agriculturist" is a good type. Other writers at this time were Walford, Holmes, Kirkpatrick, Dodge, Allen, Elliott, and Samuels. The hour was ripe, therefore, for economic ornithology really to take a place among the sciences as distinct from ornithology itself. The work carried on by Jenks (1860), Treadwell (1859), Aughey (1878), and Forbes (1880, 1882, 1883, 1903) gave the science its real foundation, and inaugurated the modern methods now well exemplified and used by the United States Bureau of Biological Survey.

At about the same time we find the science getting a start in Europe. Jenks (1860), when introducing the method of stomach examination into the United States, followed Prevost's (1858) method. M. Florent Prevost was evidently the pioneer in Europe. His paper, "A Memoir on the Alimentary Regimen of Birds," presented to the Imperial Zoological Society of Paris in the year 1858, and translated by Jenks in 1859, should still be considered a classic. In it he presents an original method of stomach examination and draws some very sane conclusions from the results of thirty years' work.

It is interesting to note that this early worker had a vision of the very method which is advocated at the present time, but which has seldom been followed in detail. He says: "It appeared that it would be of interest to gather, at different periods of the year, the stomachs of all birds which it might be possible to procure, to examine the contents, to note down the exact results of this examination, with the date of the observation, and to preserve these pieces in order to form, in time, a collection by means of which one can in the future verify each of the registered facts." He goes on to point out what he had accomplished in thirty years' work and the methods which he used in preserving stomach contents. These methods were: drying and mounting on cards, drying and preserving in a vial, and preserving in alcohol.

His method of examination appears to have been thorough, for he suggests that an "attentive examination," in many cases, made "fragments such as antennae, jaws, lips with their feelers, feet, and often entire heads" give the means of determining the family, genus, and, in some cases, even the species. Following this is a discussion of the results of the work. The tables used are described thus: "To this end I have drawn up a uniform table for all the species of birds; each copy of this table concerns a species whose name figures at the head. It represents a series of columns, of which each bears the title of an alimentary regimen; it is in these columns, and conformably to their title, that I have inscribed both the date of the observation and the indication of the objects found in the stomachs. In fine, each of these tables contains a sufficient number of lines to register observations made during twelve months of the year, and at five different dates in each month."

Early workers in America have often failed to consider the food of a bird for the whole year. They have also failed to take into consideration the fact suggested by Prevost in the following words: "The studies which I have pursued after the method indicated above will establish the fact that the same species of bird changes its food according to the age and season of the year.'' Also that ''the moment when certain insects inundate a country with individuals without number, . . . coetaneously, this very abundance seems to invite a crowd of different species of animals to feed upon them.'' It was not till 1882-1885, nearly twenty-five years later, that Forbes clearly pointed out these interrelations between birds and insects.

Prevost concludes: ''I am in the course of proving that birds are in general much more useful than injurious to our crops, and that even in respect to the greatest part of the granivorous species the evil which is done to us at certain times is largely compensated by the destruction of insects which they accomplish at other times. It is important, then, that we do not destroy these species, but only divert them from the crops when they injure them. Their destruction would permit, without counterbalance, the development of many species of insects more fatal still to agriculture. The study of the alimentary regimen has furnished me also some information which I believe useful in comprehending the reunions, the separations, and periodical emigrations which are observed so commonly among birds.'' (See Prevost, 1858, translation by J. W. P. Jenks.)

Since the work of Prevost, economic ornithology has grown rapidly. Germany has probably been most active in the work. Hawks and owls have received the most attention throughout Europe, probably for two reasons. They have been most widely attacked because of their size, and their value is most apparent upon investigation. A number of societies and institutions scattered over the continent are actively engaged in studying the economic status of birds. Chief of these are the Kaiserliche Anstalt für Land- und Forstwirtshaft zu Berlin, Ornithologische Gesellschaft in Bayern, Paris Museum of Natural History, and the Königlich Ungarische Ornithologische Centrale. The names of Berlepsch, Rey, Custer, Rörig (1903), and Hollrung (1906) have become well known as workers in this field in Germany. Rörig is the one man who has attempted a computation of the comparative amounts of food by a weight method. Csiki (1909) and Greschik (1910, 1911) have been the principal workers in Hungary. Their researches have been mainly confined to the birds of prey.

A committee appointed by the British Association for the Advancement of Science is now investigating the feeding habits of British birds by a study of the contents of the crops and gizzards of both adults and nestlings, and by collation of observational evidence, with the object of obtaining precise knowledge of the economic status of many of the commoner birds affecting rural science. Data as to the environmental conditions under which the bird was feeding and the available food supply are obtained with each specimen. All data obtained from the stomach examination are tabulated, and the weight of the bird and the condition and weight of the gizzard contents are recorded.

The United States Department of Agriculture has carried on the most extensive work in economic ornithology ever attempted by one institution. Study along this line was begun in 1885. Since that time over sixty thousand stomachs of birds have been examined, and the results, with the addition of data collected in the field, have been published in more than one hundred and thirty bulletins.

Other investigations have also been conducted. The most extensive work has been done in Illinois by the pioneer economic ornithologist, Professor S. A. Forbes. Massachusetts, Wisconsin, and Pennsylvania have also carried on investigations, the work being done by Forbush (1908), King (1883), and Warren (1888) respectively. Practically every state has been supplied with some literature on the subject by the state university or the agricultural experiment station.

At the third ornithological congress at Paris in 1900, the section of economic ornithology and bird preservation reported in favor of urging all countries and even their governments to take up seriously the subject of the utility or harmfulness of birds as being of the greatest economic importance. It was urged that "inquiries should be instituted on regular business lines, that migratory and non-migratory species alike should be observed during every month of the year and for several years in succession, that the contents of their stomachs should be carefully noted, and lists prepared of their action towards the farmer's crops."

The amount of careful work along these lines which has been done since this time is very encouraging. The last few years have seen a number of the leading magazines take up the subject of the economic value of bird life, and with illustrated articles they have brought to the attention of many the value of birds to the farmer.

Largely because of their depredations, the demand for an intimate knowledge of the food of birds has become very pressing, and yet it is interesting to note that attention to the economic side of ornithology was not aroused by the depredations of birds, but by the depredations of insects.

A comparison of the methods used up to the present will clearly show the progress which has been made in the science of economic ornithology. Such a comparison is afforded by the following sequence of methods used in determining the economic value of birds:

Sequence of methods used in determining the economic value of birds:

1. Observational notes on the food of birds. (Wilson, 1808-1814; Audubon, 1827–1838.)
2. Critical observational study of the food of birds. (Le Baron, 1855; Holmes, 1857; Weed, 1903.)
3. Examination of the stomach contents of birds. (Jenks, (King, 1883.)
4. Experimental feeding of captive birds. (Treadwell, 1859.)
5. Observation plus stomach examination. (Aughey, 1878; Judd, 1902.)
6. Observation plus stomach examination plus experimentation. (Forbes, 1903; U. S. Biological Survey.)

Similar progress can be noted in the methods used in determining the food of birds. Their sequence has been as follows:

1. Investigation of food with no reference to time or locality. (King, 1883.)
2. Investigation of food at time and locality of depredations. (Forbes, 1903; Wilcox, 1892; Aughey, 1878; Bryant, 1911, 1912d.)
3. Investigation of food according to the month, regardless of exact locality. (Jenks, 1860; Beal, 1907, 1910.)

4. Investigation of food according to the month in the same locality. (Forbes, 1903; Bryant, 1912a.)

5. Investigation of food according to the month in the same locality, with a comparison with many different localities. (See p. 454.)

The determination of the economic status of birds has likewise progressed. The sequence of the criteria used has been as follows:

1. Inferential evidence.
2. Circumstantial evidence.
3. Number of injurious insects eaten.
4. Proportion of percentage volume of injurious, neutral, and beneficial insects and seeds destroyed.
5. Contrast of all harm vs. all good, including knowledge as to life-history.

From these comparisons it can be seen that great progress has been made. To infer that a bird is injurious simply because it is seen in a grain field or orchard, or to brand it as injurious because of circumstantial evidence in the form of grain or fruit found in the stomach, are obsolete methods today. Furthermore, we recognize at the present time that a bird may eat some beneficial insects and still be a valuable bird. Nothing less than a knowledge of the food for the whole year, combined with a knowledge of the life-history of the bird concerned, allowing a balance of all the benefits conferred with all the damage done, meets the requirements of the present.

INVESTIGATION OF THE ECONOMIC STATUS OF THE WESTERN MEADOWLARK IN CALIFORNIA

Interest centered around the meadowlark for some time previous to the institution of an investigation. A rather dormant complaint against the depredations of the meadowlark in sprouting grain fields was brought to a head in a bill (no. 229) introduced by Assemblyman Stuckenbruck of San Joaquin County into the State Legislature on January 11, 1909. The bill, which proposed to amend section 637 of the penal code of California, passed through the committee, but was refused passage, the vote standing 32 to 28. On the motion to reconsider, the bill was again brought to a vote and passed with a vote of 41 to 28. The Committee on Fish and Game of the Senate reported favorably on the bill, but it was refused passage on a vote of 17 to 12.

In 1911 Assemblyman Stuckenbruck, at the request of his constituents, introduced a similar bill with the proviso that in the counties of Tehama, Butte, Sutter, Sacramento, Yolo, Colusa, Glenn, San Joaquin, Stanislaus, Tulare, and Kings the meadowlark be not included among the birds protected by the act, hoping thus to allay the opposition met from other parts of the state at the former session of the legislature. This bill, being referred to the Committee on Fish and Game, was returned to the Assembly with a majority report in favor of its passage and a minority against its passage. It failed of passage on March 20.

Continued complaints from the farmers and fruit growers of the state have been made to the State Fish and Game Commission regarding the losses to crops caused by the depredations of birds. The commission has been repeatedly urged to take strong measures to avert the damage done. The usual measure urged is that the particular bird in question should be placed on the unprotected list. On the other hand, many scientists and others interested in birds have pointed out the fact that birds confer a great benefit in keeping down the number of injurious insects and weed seeds, and thus they fill a niche in the economy of nature most suited to mankind which is not and can not be filled by any other form of life. Experience has shown that many belonging to the first class have based their complaints on circumstantial or partial evidence or on evidence not sufficiently reasoned out. Furthermore, these complaints have brought out the fact that really very little is known of the food habits of birds of California. Certain it is that a knowledge of the food habits of a bird is necessary to a determination of its economic status. As a result, therefore, the commission thought it wise that legislation should be based on scientific investigation as to the value of birds, and not on circumstantial evidence. Consequently an investigation into the relations of the birds of the state to agricultural and other interests was instituted.

The institution of the investigation was largely due to the interest and energy of Mr. John P. Babcock, Chief Deputy of the California State Fish and Game Commission, 1910–11, and Professor Charles A. Kofoid of the Department of Zoology of the University of California.

A COMPARISON OF METHODS IN ECONOMIC ORNITHOLOGY

The attempt to show the amount of the different kinds of food contained in the stomachs of birds has led to the use of two distinct methods, both of which must be considered valuable, and both of which approximate the end sought. A method introduced by King (1883), and later used by Newstead (1908), gives the total number of birds taking the different kinds of food compared with the total number of stomachs examined. The second method, employed by the United States Biological Survey, depends entirely upon the comparative volume of the different kinds of food found in the stomach, calculated in per cent of total volume and averaged. A third method, in which actual counts of the insects found are made, has been used in a few instances (Mason and Lefroy, 1912; Fisher, 1893). Workers in this field in Great Britain have used the numerical system almost entirely, depending for a criterion upon the number of birds taking a certain kind of food.

Since all of these methods appear to furnish certain information not furnished by the others, a combination of all three methods has been used in this investigation. Dependence is laid on the first method for an idea of the percentage of birds of a species feeding on a particular insect, on the second for an idea of the comparative amounts of the different kinds of food taken by individuals and by the species, and on the third for an idea of the actual numbers of the different elements of food. The counting of weed seeds and insects found in the stomach of a bird is difficult and fruitful of error. Yet the fact that smaller numbers are always counted than truly exist, owing to the comminuted condition of some, makes it evident that no exaggeration is possible here. Consequently it affords dependable evidence as to the numbers of weed seeds, insects, etc., taken by a bird. On the other hand, the percentage-of-volume method can be depended upon only to furnish an idea of the comparative quantities of the different kinds of food. Personal error in estimating has to be allowed for in this method, for whereas a certain insect might be to the eye of one person ten per cent of the volume, it might represent fifteen per cent to the eye of another.

The furnishing of complete data as to the bird whose stomach is examined (date, locality, kind of field, collector, etc.) should afford information, first, as to the variation in the amount of food taken by birds during the day, month, and year, and second, the food preference of birds in a given locality and in different localities. The record of the exact time of day, the month, and year when the bird was collected furnishes the basis for the first, the record of the habitat, as, for example, the kind of field, orchard, or vineyard, the basis for the second.

An attempt has also been made to improve the method used in determining the economic status of a bird. As has already been pointed out, the economic status of a bird was originally determined by inference. A bird in the grain field must be eating grain and therefore is injurious. Experience has taught that such reasoning is fraught with error. And further experience has taught us that even though a bird may cause considerable damage, yet because of its usefulness as a weed-seed destroyer, as an insect destroyer, or as a bird important in keeping the balance in nature most suited to man, it may be more beneficial than harmful. At one time the total good accomplished by a bird was held to inhere in the number of injurious insects it destroyed. Today, although we still retain this idea, we see a little further and conclude that a bird may be beneficial because it destroys insects (almost all insects being potentially destructive), and not because it chooses a particular class of insects arbitrarily classified as harmful by man.

An attempt has been made to arrive at the average volume of food taken by the meadowlark, by determining the volume of food contained in a large number of stomachs in cubic centimeters and taking an average volume. This allowed the recording of each stomach as being of average volume, over the average, or below the average.

Identification of the various insects and weed seeds found in the stomachs has been difficult. Help from the experts of the United States Department of Agriculture, from the Department of Entomology of the University of California, and from others has facilitated greatly the identification. Certain field work, embracing studies of the abundance of birds, the depredations of birds, nesting habits, the relation of the birds to insect outbreaks, the kind, amount, and availability of food, and the time of digestion, has afforded needed supplementary information.

In addition to the importance of this investigation to agricultural interests, it has been fruitful of valuable data from the standpoint of science. Although the investigation has been carried on primarily to furnish practical information as to the exact relation of the western meadowlark to agriculture and horticulture, yet no pains have been spared to collect data of purely scientific interest. The importance of a knowledge of life-histories has been emphasized only of late. Information as to the food of any form of life constitutes one of the most far-reaching phases of its life-history. As Forbes (1903) pointed out: "Since the struggle for existence is chiefly a struggle for subsistence, a careful comparative account of the food of various competing species and genera, at different places and seasons and at all ages of the individual, such as has not heretofore been made for any class of animals, cannot fail to throw much light upon the details, causes and effects of this struggle. The flexibility of the food habits of the widely ranging species, the direct effects of normal departures from the usual average of food elements upon the origin of variations, and the general reactions of birds upon their organic environment, are examples of subjects upon which light should be thrown by this investigation."

In this investigation the difference in food habits of the nestling and adult has been clearly demonstrated by the examination of a large number of specimens. The difference in the kind and amount of food taken by the two sexes is made available for the first time. Field investigation has been fruitful of an increased knowledge of the general habits, nesting habits, abundance, depredations, and distribution of the western meadowlark.

The handling of so large a number of specimens taken from all parts of the state and during each month of the year has furnished information as to variation, albinism, parasitism, and malformation. Critical evidence as to the value of certain so-called protective adaptations of insects has also been afforded. The investigation of the relation of birds to insect outbreaks has emphasized their importance at such times and furnished critical evidence as to the interrelations of these organisms.

THE WESTERN MEADOWLARK (*STURNELLA NEGLECTA*)

In spite of its name, the western meadowlark is not a true lark, but belongs to the family Icteridae along with the blackbirds and orioles. It is easily recognized by its medium size, gray- and brown-streaked back, brilliant yellow throat, black V-shaped collar, and its conspicuous white outer rectrices.

The meadowlark is widely distributed over North America. The eastern meadowlark (*Sturnella magna magna*) differs from the one found in the west in size, color, and song. The western meadowlark is slightly larger than the eastern bird, is paler in color, and has a much richer song. For these reasons the western form is considered a distinct species and is called the western meadowlark (*Sturnella neglecta*).

It is found from Wisconsin, Illinois, Iowa, Texas, etc., west to the Pacific Coast, and from central and western Mexico to British Columbia and western Canada. It is to be found throughout the State of California from sea level to 7000 feet elevation in the mountains.

The western meadowlark is resident throughout the year. A slight altitudinal migration perhaps takes place, governed largely by the available food supply, but usually the bird is to be found in the same general locality throughout the year.

The western meadowlark is a conspicuous bird of treeless areas and a frequenter of meadow, pasture, or uncultivated grass land. Although a poor flyer when compared to some birds, the meadowlark, with its peculiar hovering flight, is possessed of a method of locomotion sufficient for its needs. Its mode of life necessitates but a small amount of flying.

During the fall and winter months meadowlarks gather in flocks of five to fifty or more. During the spring, however, they are seen singly or in pairs. Of a nervous temperament, they are wary and do not often allow of close approach. Both the male and female are good singers. Their cheerful and varied song is sometimes given from mid-air, but more often from a fence post, shrub, or clod.

The western meadowlark appears to be one of the few birds which is profiting by the increased cultivation of land. Alfalfa furnishes particularly good food and cover for the bird, and grain fields are often chosen for a home. With the furnishing of still more good food and cover, combined with the destruction of some of its enemies, this bird may be expected still further to increase in numbers.

The western meadowlark feeds almost exclusively on the ground. It seldom perches in a tree of any kind. The early morning hours are spent in obtaining food, whereas the middle of the day is usually spent quietly hiding in the grass.

The food, composed largely of insects, grain, and weed seeds, is procured not only from the top of the ground, but also by probing beneath the soil and by searching under clods, manure, etc. Alfalfa and grain fields appear to be the favorite feeding grounds of these birds in cultivated districts.

FIELD INVESTIGATION

Next to the knowledge of the food of a bird in determining its economic status is a study of the bird at the scene of action, or, in other words, a knowledge of the habits of the bird. Evidence along this line can be afforded only by field investigation.

Over a month's time was spent at Lathrop, San Joaquin County, California, studying the abundance, feeding habits, nesting habits, depredations, etc., of the western meadowlark. As has been stated, this particular locality was chosen because it afforded not only an abundance of birds, but also a favorable proportion of cultivated and uncultivated land, thus allowing a study of food preference.

The field work carried on can be grouped under three heads: studies of the abundance, of the habits, and of the depredations. Studies of the relations of birds to insects and to insect outbreaks have also been included in the field investigation, but will be discussed in another place. (See p. 456.)

Abundance of the Western Meadowlark

Several findings in connection with the field work have tended to minimize somewhat the depredations of the meadowlark. Perhaps one of the most important is the preference which the bird shows for uncultivated land. Censuses have absolutely demonstrated that, during hours of feeding, western meadowlarks are more abundant in pasture land than in cultivated fields. Evidence as to the abundance of the western meadowlark is also afforded by the censuses.

The following are censuses taken in the vicinity of Lathrop, San Joaquin County, on a two and one-half hour drive:

	Uncultivated (Pasture)	Cultivated (Grain and alfalfa)
February 28, 1912	158	65
May 31, 1912	69	27

These two censuses covered practically the same length of time and the same territory. As the birds were seen in flocks in February, it is only natural that more birds were recorded. May being in the nesting season, the birds were then more widely scattered and not so easily seen. It is apparent that the meadowlark prefers uncultivated land even at the time of feeding. A similar census taken at Acampo, San Joaquin County, during an hour's walk (2–3 P.M.), resulted as follows:

	Number
Orchards, vineyards, and pasture	25
Grain fields	2

Meadowlarks were more abundant in the vicinity of Lathrop than in the vicinity of Acampo. There is very little pasture land in the vicinity of Acampo. This, if not the main reason, is one of the important ones which account for this contrast in abundance. Another contrast in abundance can be noted from the following censuses, two taken at Los Banos, Merced County, July 11, 12, 1912, and the other at Merced, Merced County, July 17, 1912. Those at Los Banos were taken while walking less than five miles, and occupied about four and three hours respectively. The one at Merced was taken while driving about fourteen miles, and occupied the time between 1:30 and 5 o'clock.

Locality	Date	Time	Meadow-larks seen	Average per acre
Los Banos	July 11, 1912	3–4:30	36	1.0
Los Banos	July 12, 1912	2–5:15	67	1.0
Merced	July 17, 1912	1:30:5	23	.1—

It is evident, therefore, that the abundance of this species of bird is largely affected by locality. Probably in the last analysis food supply is the important factor. This brings us to the question: Can the western meadowlark obtain its natural food in cultivated fields as easily as in the uncultivated? If we consider insects as vegetable feeders, then we should expect to find the best insect supply where plant growth was most luxuriant. The cultivation of land destroys much of the natural plant growth, and therefore must diminish the food supply of the insects enough to vary the abundance. Grasshoppers, cutworms, and wireworms can usually be found more abundant in grassy pasture land than in orchards or grain fields. Hence it is a natural consequence that we find meadowlarks frequenting untilled land more often than tilled land.

The censuses taken also demonstrated the fact that meadowlarks were found in the pasture land in greater abundance during the middle of the day than in the morning hours of feeding. During the hotter periods of the day these birds hide in the grass. Open fields are seldom chosen at this time of the day.

NESTING HABITS

The nesting season of the western meadowlark lasts from March to August. The nest is a well-concealed one, built of dry grasses usually in grass, alfalfa, or grain fields, in a depression in the ground. A canopy of dry grass stems usually arches the top of the nest and a runway two to five feet long leads to the nest. Ofttimes this runway is the only clue to the location of the nest. The female bird does most of the work of incubation and feeding of the young, while the male acts as a guard. Eggs are usually five and are white, variously marked with brown, purple, and lavender spots and lines.

Work in the spring of 1911 and 1912 substantiated the fact that western meadowlarks usually nest twice each year. The first nesting usually occurs in April and May and the second in July and August. Probably on an average not more than three young are in a brood, although the number of eggs laid is usually five. Second nestings examined usually show an incomplete set of eggs. A preference for pasture land for nesting sites was shown, at least eighty per cent of the nests found being so situated. The time of incubation was found to be twelve to fourteen days. The young stay in the nest but a short time, eight to ten days. Nestlings are exposed to many enemies, such as skunks, weasels, rats, and hawks, and the number of broods successfully reared is less than that of most other birds. That over ten per cent of the nests in most localities are destroyed by predacious animals and birds seems a very conservative estimate.

These facts have an important bearing on the economic relations of the meadowlark. Proximity of breeding grounds to cultivated crops naturally has an influence on the amount of damage done. The rate of reproduction influences the amount of damage, owing to the number of individuals to be expected in any locality.

DEPREDATIONS OF THE WESTERN MEADOWLARK

No small part of the field work has consisted in investigations of the damage caused by the western meadowlark. In most cases the field work has been supplemented with stomach examinations.

The principal complaint lodged against the western meadowlark has been that this bird destroys sprouting grain. The field investigations have proved that this complaint has a real foundation. An interesting side-light on this habit is afforded by a paragraph from Coues's (1874) "Birds of the Northwest": "In April, before pairing, hundreds used to frequent daily the parade ground of Fort Randall, where, as the grass was yet scarcely sprouted, good opportunity was offered of observing their characteristic habit—one not so generally known as it should be, since it is related to the peculiar shape of the bill. The birds may be seen scattered all over the ground, busily tugging at something; and on walking over the scene of their operations, the ground, newly softened by the spring thaw, is seen to be riddled with thousands of little holes, which the birds make in search of food. These holes are quite smooth—not a turning over of the surface of the ground, but a clean boring, like that made by sinking in the end of a light walking stick; just as if the birds inserted the bill and then worked it about until the hole was of sufficient size. Whether they bored at random, or were guided by some sense in finding their prey, and what particular objects they were searching for, I did not ascertain; but the habit was so fixed and so continually persevered in as to attract general attention."

This habit of boring into the ground to obtain sprouting seeds and possibly insects is therefore a habit of old standing, and is not one recently developed.

A careful investigation of a sprouting grain field where meadowlarks are abundant will demonstrate to any one that the western meadowlark pulls sprouting grain. At times the drill row is followed for distances of four to six feet and apparently every sprouted kernel is pulled up (pl. 21, fig. 1). With its long awl-like bill, the meadowlark bores down beside the sprout, grips the kernel and pulls it up. The kernel is occasionally eaten, but more often it is simply crushed in the bill to obtain the milk and then dropped (pl. 21, fig. 2). Consequently stomach examination cannot be relied upon to furnish accurate evidence as to the total amount of grain thus destroyed.

Certain fields examined have given evidence that the deeper furrows made by drills were most frequented by the birds.

Whether this was due to the better cover or to the ease with which the sprouting grain could be obtained it is impossible to state.

Where meadowlarks are very numerous and the field of grain small and isolated, considerable damage results. In some cases such fields have had to be resown. Since the loss of a small patch of grain means far more to the small farmer than does a larger amount of grain to the large rancher, the bird's depredations here are important. The investigations have shown, however, that fields apparently badly damaged by meadowlarks when the grain was sprouting yielded the usual crops at harvest time. This can be accounted for in this way: The birds can succeed in pulling the grain for only a short period of time after it appears above the ground. By the time the second and third leaf appear the plant is well enough rooted so that the loss of the kernel, even if it should be removed, would not injure the plant. Consequently the apparent devastation is largely minimized by the further sprouting of other kernels and the successful survival of the sprouts of many of the kernels removed. A certain amount of thinning may at times indeed be desirable. The lack of uniformity in the thinning accomplished by meadowlarks is, however, an argument against them.

Broadcasted grain, unless harrowed in very deeply, suffers more than drilled grain. It is the universal verdict of the grain ranchers of the state that deeply drilled grain suffers less than the shallowly drilled or the broadcasted grain. Experiments have shown that the greatest yield comes from drilled grain.

The following table is from University of California Publications, Agricultural Experiment Station, Bulletin 211:

RELATIVE RESULTS FROM DRILLED VS. BROADCAST SEEDING UPON THE YIELD OF GRAIN

	Average of 22 trials	
	Barley	Wheat
Drilled	70.80	34.85
Broadcast	64.43	31.60
	6.37 bu.	3.25 bu.
Percentage increase	9.9	10.3
Money value	$3.18	$3.12

The proper depth for grain to be planted in sandy soil is three to four inches. If all grain were planted at this depth very little damage would be possible, for meadowlarks are unable to bore more than two and one-half inches at most. Holes measured average about an inch and a half in depth.

Margins of fields bordering pasture land usually suffer most. Ofttimes a noticeable difference in the amount of grain growing along the edges of fields can be attributed to the work of meadowlarks.

Owing to the concentration of large numbers of meadowlarks on a single field, fields of grain planted early suffer most from the depredations of these birds. Grain sown late in the year suffers much less, for insects become available in small numbers and there is less concentration of damage, due to the larger amount of available food.

Meadowlarks are more able to obtain grain planted in sandy soil. Their ability to bore deeply into soil after kernels of grain varies directly with the hardness of the soil. Hard, dry, adobe soil precludes attack. Sandy soil, especially after being softened by a rain, is easily manipulated to advantage.

An apparent preference of the birds for oats has been shown not only by field investigation, but by the complaints of the ranchers also. Probably its availability is a greater factor than any preference shown by the bird. That less damage is possible to wheat and barley because the kernel is more easily removed without damage to the plant is one theory proposed. Certain it is that there is a difference in the damage to adjoining fields of oats and barley.

Beyond an occasional instance of meadowlarks pulling sprouting garden seeds, the only other complaint of importance is that they destroy melons by boring holes in them. Most of the complaint has come from the San Joaquin Valley, and especially from Delano and Pixley, Kern County. Melon growers, although admitting that meadowlarks cause considerable damage to melons, have been unable to demonstrate the actual damage in the field. Opinion is divided as to whether they cause any damage. Some prominent growers affirm they are never troubled. Others complain of a considerable loss. For instance, the names of two melon growers in the vicinity of Dinuba, Tulare County, were handed in as those of men who were greatly troubled. One returned a verdict of "not guilty," and the other reported that the damage was not very great. All of the growers report that as soon as there are broken melons in the field the birds cease to be troublesome. Apparently the depredations of meadowlarks on melons have been exaggerated.

There is evidence to support the view that meadowlarks bore into the melons to obtain water. Whether or not they are attracted by the sweet taste we cannot say. The placing of water in a field as an experiment would doubtless confirm or disprove this view.

An occasional complaint that meadowlarks are injurious to grapes has been received. Inquiry in grape-growing sections of the state has led to the conclusion that such damage is negligible. A number of birds are destructive to grapes, chief of which are the oriole and grosbeak. Both of these birds are well known as fruit eaters. The meadowlark, on the other hand, seldom turns its attention to fruit of any kind. No damage to grapes caused by the meadowlark has been noted in the field.

Investigations of the damage caused by meadowlarks has led to the following conclusions:

1. The western meadowlark is destructive in sprouting grain fields, because of its habit of drilling down beside the sprout and pulling up the kernel. The amount of damage done is dependent on the particular location, the abundance of the birds, the character of the soil, the time of year, depth and method of planting, and the kind of grain. The damage to oats is greatest, wheat suffers considerable damage, whereas barley suffers but little. Broadcasted grain suffers more than drilled, because not being sowed so deeply it is more easily obtained by meadowlarks. The birds often follow the drill row and pull almost every kernel. Occasionally, where meadowlarks are very numerous and the quantity of grain small, fields have had to be resown. The real amount of damage done has evidently been overestimated, for fields apparently badly damaged have given the average yield later in the year. After the second and third leaf appears on the grain, the bird can do little damage. This fact reduces the

duration of their depredations to less than two weeks, and consequently minimizes the amount of destruction possible. Deep planting and drilling as against broadcasting are important as measures for protecting crops.

2. Damage to other cereals, such as corn and maize, and to fruit is negligible.

3. Investigation of complaints that meadowlarks are destructive to melons has shown that damage caused in this way has been exaggerated. Melon growers, although claiming that the birds cause considerable damage, have often been unable to demonstrate the actual damage in the field.

4. Censuses have demonstrated that the western meadowlark prefers grass land to cultivated land, nearly forty per cent more birds being found in the former.

EXPERIMENTATION ON CAPTIVE BIRDS

Experimentation on captive birds as a means of determining food preference has been suggested by Forbes (1903) and Judd (1901). No doubt such experimentation furnishes considerable evidence as to the food preference of the bird if carried on with proper controls. Thus far this sort of experimentation has not furnished dependable generalization as to what the bird would have taken under natural conditions (McAtee, 1912). This does not mean that better devised and controlled experiments would not furnish dependable evidence.

The difficulty of keeping in cages birds with the temperament of the western meadowlark and the difficulty of procuring for them proper food has prevented the use of feeding experiments in this investigation.

In order properly to estimate the quantity of food consumed daily it has been necessary to determine the time of digestion. It was in this determination, and in the determination of the quantity of food, that experiments on captive birds became of value.

There are four methods of determining the quantity of food required by young birds. First, the quantity of food carried to the young by the parents may be observed; second, the stomach contents may be examined and the quantity estimated; third, experimental feeding of caged birds may be used; and fourth, the quantity of food may be determined by a daily weighing of nestling birds and of their excreta.

The first method, owing to the difficulty of observing in the field the feeding of the young of so shy a bird as the western meadowlark, has been largely neglected in the interest of the other more practical methods. However, some observations as to the number of trips to the nest made with food have been made. In one instance a female western meadowlark carried food to the nest three times in twenty minutes (6:15–6:45 A.M.). As the presence of the observer caused some nervousness on the part of the parent birds, this cannot be considered the normal rate.

AMOUNT OF FOOD REQUIRED BY WESTERN MEADOWLARKS

Stomachs of nestling western meadowlarks examined contained as high as two grams of insect food. Maxima of seven large cutworms, of twelve grasshoppers (three-quarters of an inch in length), and of eight beetles have been found in the stomachs of nestlings. One stomach contained twenty-four ants and parts of a ground beetle. The volume of nestling stomachs and of their capacity in terms of the common elements of food follows:

Volume of average cutworm	.5 c.c.
Volume of average ground beetle	.3
Volume of average grasshopper	.75
Volume of average stomach of ♂ western meadowlark	3.00
Volume of average stomach of ♀ western meadowlark	2.50
Capacity of average ♂ stomach in cutworms	6
Capacity of average ♀ stomach in cutworms	5
Capacity of average ♂ stomach in ground beetles	10
Capacity of average ♀ stomach in ground beetles	8
Capacity of average ♂ stomach in grasshoppers	4
Capacity of average ♀ stomach in grasshoppers	3

A nestling western meadowlark after obtaining no food for three hours was fed twenty-eight small grasshoppers (one-half inch in length), equal in volume to about three cubic centimeters. Another one was fed four grasshoppers (one inch in length), twelve small grasshoppers (one-half inch in length), one robber fly, one beetle, and five ants. A third one was fed thirty grains of wheat inside of ten minutes.

Weighings of nestling birds demonstrated the fact that they gained very nearly seven grams (0.6 ounce) in weight daily. Solid excreta averages 0.48 gram. The weight of excreta voided during twenty-four hours must be near 3.6 grams, thus making the weight of food required daily over ten grams. This computation does not take into account the weight of excretory products given off through the skin or the weight of carbon dioxide given off through respiration. The ratios of solid, liquid, and gaseous excreta are not known. The tabular results of weighings follow:

WEIGHINGS OF NESTLING MEADOWLARKS

	Time of weighing		Average weight of 2 western meadowlark nestlings		
Date	Nest No. 1	Nest No. 2	Nest No. 1		Nest No. 2
May 26	6:00 a.m.	....	.75 oz.		
May 27	8:30 a.m.	....	1.25		
May 28	8:40 a.m.	....	1.50		
May 29	7:15 a.m.	5:45 p.m.	1.75	.75 oz.	.50 oz.
May 30	7:45 a.m.	5:00 p.m.	2.9	1.00	.75
May 31	4:25 p.m.	....	2.0	......	......
June 1	7:30 a.m.	6:30 a.m.	2.25	1.50	1.25
June 3	....	6:15 a.m.	......	1.75	1.50

Weight of egg ready to hatch	.135 oz.
Weight of day-old nestling	.25
Weight of eight-day-old nestling	2.50
Weight of average adult	4.00

Although more experiments are necessary to establish the exact gain in weight of nestling birds, yet these experiments have furnished evidence as to the enormous quantities of food consumed by nestling birds. When one considers that there is a gain of about three ounces (93.3 grams) in weight inside of two weeks, and that this added weight must be calculated by the weight of food consumed minus the waste thrown off in the various forms of excreta and expired air, the quantity of food necessary is evident. Not only is enough food needed to maintain energy, but an additional amount to maintain weight increment is demanded during the period of growth. Probably each young western meadowlark consumes something like five ounces (155.5 grams) of food during the time it remains in the nest. This weight in grasshoppers would mean 311 individuals and in cutworms 415 individuals.

The time of digestion of the western meadowlark was determined by feeding captive juvenile birds and examining the condition of the food at intervals after feeding. The following table gives a summary of the results of these experiments:

Tabular Results of Experiments on the Time of Digestion

Experiment	Time without food	Time between feeding and killing	Food given	Condition of food on examination
1	3¾ hrs.	2 hrs.	4 large grasshoppers (*Camnula pellucida*) 12 small grasshoppers 1 robber fly 1 beetle (*Coniontis* sp.) 5 ants	Finely comminuted and largely digested
2	5¾	3¾	20 grasshoppers (*Camnula pellucida*) 10 ants	About one-quarter of volume remained; all soft parts digested
3	3¼	2	30 kernels wheat	15 kernels left undigested; hulls still undigested
4	3½	2	1 May beetle (*Ligyrus gibbosus*) 1 weevil (*Rhygopsis* sp.) 12 grasshoppers (*Camnula pellucida*)	Only hard parts left in stomach (heads, wing-covers knee joints, etc.)
5	4	5?	28 grasshoppers	Stomach empty

From these data it can be safely concluded that insects are digested in two to four hours and that the stomach is completely emptied every four hours. Beetles and ants, owing to the chitinous parts, remain longer in the stomach than do grasshoppers. Cutworms doubtless are digested much more rapidly. Grain is more difficult to digest than insects and remains in the stomach longer (four to five hours).

These results compare very favorably with the results of similar experiments by other investigators. Experiments carried on by Treadwell (1859), Forbush (1907), and Weed and Dearborn (1903) have demonstrated that birds have a very rapid digestion, most of them requiring from one to four hours only to digest a meal. All evidence of food had disappeared from the excreta of a crow within two and one-half hours after feeding. Professor Treadwell showed that juvenile robins digested a meal every two to four hours.

All evidence, therefore, points to the fact that four hours can be considered a sufficient period of time to assure the digestion of the stomach contents of a western meadowlark. The contents of the stomach at the time the bird is killed must have been taken within four hours previous to the collection of the bird. The daily consumption must, therefore, be considered about three times the capacity of the bird's stomach. As the birds start each day with an empty stomach and with the additional stimulus of hunger, the greater amount consumed during early morning hours compensates for the smaller amount taken during the middle of the day.

EXAMINATION OF THE STOMACH CONTENTS

Collection and Preservation of Material

Birds in sufficient numbers to furnish reliable data, collected every two weeks during a year, and from over twenty different localities in the state, have been made available through the co-operation of the deputies of the Fish and Game Commission. Each bird was tagged with data as to date, time of day, locality, kind of field or orchard, and collector. Dependable data regarding abundance of food were not available as a general rule. The birds were then preserved in formalin. On the arrival of shipments at the laboratory the stomach (gizzard) was removed and data as to the species and sex of the different birds added. The tag bearing complete data was then wrapped with the stomach in a small cloth, and preserved in ten per cent formalin until microscopically examined.

In determining the localities where collections have been made an attempt was made to select well-settled parts of the state representative of the different agricultural sections. The following instructions were sent to each deputy:

INSTRUCTIONS TO COLLECT BIRDS FOR SCIENTIFIC INVESTIGATION OF THEIR RELATION TO AGRICULTURE

Dear Sir:—

In order to obtain material for our field investigation of the relations of game and other birds to agriculture, we propose to collect specimens of all the field and orchard birds in the State other than quail, ducks, geese, and crows during the first and third week of each month.

We want especially one-half dozen each of meadowlarks, robins, and blackbirds collected during these weeks in grain fields and the same number in vineyards or orchards in sections where there are both. We want, also, two doves from the same section for each of the two weeks mentioned. For the present we will confine our attention to meadowlarks, horned-larks, robins, and blackbirds. Where practicable obtain specimens of each species of your district from the same field or fields of a like character near by, because we wish to show just what they feed upon throughout the year.

As each bird is killed fill out one of the string record tags furnished you, being careful to note the hour, date, character of field, orchard or vineyard, the location and the name of the owners and the nearest post-office. Then securely fasten a tag to each bird. In writing upon the tags use plain lead pencils only, as the preserving fluid will destroy ink and indelible pencil marks.

After filling out the tag, attach it to the bird and then record in a notebook devoted to this work a similar record to the one on the tag.

Upon returning from the field proceed to preserve the specimens as follows: From any drug store purchase a 40 per cent solution of formalin or formaldehyde. Then place in an ordinary two-quart fruit jar one-half pint of the 40 per cent formalin and then fill up that jar with clear water and mark it "Jar No. 1." Then place your specimens in another jar (or jars) and fill it with the liquid from "Jar No. 1," and seal the top to prevent evaporation. Don't place too many specimens in a jar; give them room enough to become thoroughly saturated. Keep the specimens in the solution for at least a week. See that the tag of each specimen is uninjured.

At the end of each month take your specimens from the solution and wrap in a cloth wet from the solution in "Jar No. 1" and place in a thin cracker box or a tight wooden box and ship as hereafter directed, together with a copy of the record from your notebook.

The solution from which you remove your specimens can be used several times, supplying the necessary additional solution from "Jar No. 1."

Recember that birds have no value unless each is securely tagged with a record of the hour, date, etc.; that our work depends absolutely upon the accuracy and reliability of the record. Send separate bills covering your purchase of shot, formaline, jars, traveling and other expenses connected with this work to this office. Do not include them on your regular bills.

The necessary permit to take these birds throughout the year is furnished you herewith.

Inform your local press and others interested just what you are doing and the object we have in making this collection, to wit, investigating the relations of our birds to agriculture, so that there may be no misunderstanding.

Finding that it worked a hardship on the deputies to spend certain days of each month collecting birds, the original instructions were modified as follows:

Our order concerning the collection of non-game birds, for scientific investigation, is hereby modified to permit collecting at *convenient times* instead of during the *first* and *third* weeks of each month. The collection, however, must be distributed evenly so that nearly the same number of specimens are secured in each bi-weekly period.

Under this order we believe the deputies themselves can, while on other duty, take all the specimens needed for our work and thereby greatly reduce expense. In consequence we direct that all special collectors be dismissed and their permits and collecting material taken over by the regular deputies responsible for their engagement.

Material

The accompanying map (fig. A) shows the localities in which collections have been made. The localities from which complete series, that is, birds collected each month of the year, were made, and those localities from which incomplete series were obtained, are both indicated. The attempt was made to have a minimum of six specimens collected each month. In several instances collections of a dozen birds each month were obtained.

In order that the work of 1911 might be verified, collections were continued at Live Oak, Sutter County; Sacramento, Sacramento County; Newman, Stanislaus County; and Salinas, Monterey County, during 1912. This afforded a comparison of the food in two successive years, and has acted as a check on the results obtained the first year.

A total of 2070 stomachs of western meadowlarks has been available for examination, of which number nearly two thousand have been examined and the results tabulated. The largest collection available, composed of one hundred and seventy-five birds, was from Hanford, Kings County. The largest number available taken in a single month was twenty-four.

I.—Table Showing Material Suitable for Stomach Examination

Locality	Collector	Number of meadowlarks	Number of months represented	Numbers taken: In grain fields	In orchards	In vineyards	In pasture land	In alfalfa fields	In gardens	In ploughed fields	In bean fields	In beet fields	In corn fields	In miscellaneous fields
Eureka, Humboldt County	W. C. Graham, E. C. Barnes	69	12	37	7	......	21	......	......	......	......	......	......	4
Anderson, Redding, Sisson, Siskiyou County	J. S. White, A. E. Doney	30	9	9	9	......	3	4	......	......	......	......	......	5
Ukiah, Cummings, Mendocino County	B. H. Miller, Wm. Ray	72	7	32	14	9	......	12	......	......	......	......	......	5
Healdsburg, Sonoma County	H. Lencioni	20	3	20	......	......	......	......	......	......	......	......	......	......
Red Bluff, Tehama County	T. W. Birmingham	159	12	82	77	......	......	......	......	......	......	......	......	......
Live Oak, Sutter County	E. D. Ricketts	105	19	98	1	......	......	......	......	......	......	......	......	6
Susanville, Plumas County	F. P. Cady	6	1	6	......	......	......	......	......	......	......	......	......	......
Grass Valley, Nevada County	R. O'Connor	18	9	16	1	......	......	......	......	......	......	......	......	1
Napa, Napa County	W. J. Moore	29	9	13	7	......	7	......	......	......	......	......	2	......
Sacramento, Sacramento County	Geo. Neale	60	13	22	......	4	30	3	......	......	......	......	......	1
Stockton, Lathrop, San Joaquin County	Geo. Merritt, H. C. Bryant	31	6	18	......	1	12	......	......	......	......	......	......	......
San Andreas, Calaveras County	C. W. Getchell	6	1	3	......	......	2	......	......	1	......	......	......	......
Pleasanton, Alameda County	E. Downing	44	9	26	......	14	......	1	......	3	......	......	......	......
Newman, Stanislaus County	J. E. Newsome	147	23	141	......	......	6	......	......	......	......	......	......	......
Los Banos, Merced County	J. M. McSwain, H. C. Bryant	94	6	83	2	2	7	......	......	......	......	......	......	......

I.—Table Showing Material Suitable for Stomach Examination—*Concluded*

Locality	Collector	Number of meadowlarks	Number of months represented	Numbers taken: In grain fields	In orchards	In vineyards	In pasture land	In alfalfa fields	In gardens	In ploughed fields	In bean fields	In beet fields	In corn fields	In miscellaneous fields
Madera, Madera County	J. H. Perry	18	2	18	......	......	......	......	......	......	......	......	......	......
Fresno, Fresno County	S. L. N. Ellis	3	1	3	......	......	......	......	......	......	......	......	......	......
Hanford, Kings County	E. W. Smalley	184	12	46	30	7	13	88	......	......	......	......	......	......
Hollister, San Benito County	C. A. McHenry	67	9	52	1	1	5	......	......	......	......	......	......	8
Salinas, Monterey County	F. Shook	50	7	16	14	......	......	......	......	......	......	......	......	20
Santa Maria, Santa Barbara County	H. J. Abels	19	2	10	2	......	......	......	......	......	......	5	......	2
Big Pine, Inyo County	E. H. Ober	71	12	34	9	7	5	5	10	......	......	......	......	1
Bakersfield, Kern County	A. C. Tibbett	6	1	6	......	......	......	......	......	......	......	......	......	......
Ventura, Ventura County	J. E. Kuhlman	44	5	17	......	......	......	7	......	......	15	5	......	......
San Bernardino, San Bernardino County	J. A. Vale	110	12	99	......	11	......	......	......	......	......	......	......	......
Riverside, Riverside County	C. H. Vosburgh, J. H. Gyger	117	11	38	2	......	1	63	......	......	......	......	......	13
El Toro, Orange County	W. K. Robinson	169	12	92	1	9	43	......	......	......	6	......	......	18
San Diego, San Diego County	Webb Toms	138	12	73	57	7	......	......	......	......	......	......	......	1
Imperial, Imperial County	G. H. Dexter	18	1	10	......	......	......	6	......	......	......	......	......	2
Miscellaneous	H. C. Bryant	16	3	......	......	......	15	......	......	......	......	......	......	1
	Totals	1920		1120	234	72	170	189	10	4	21	10	2	88

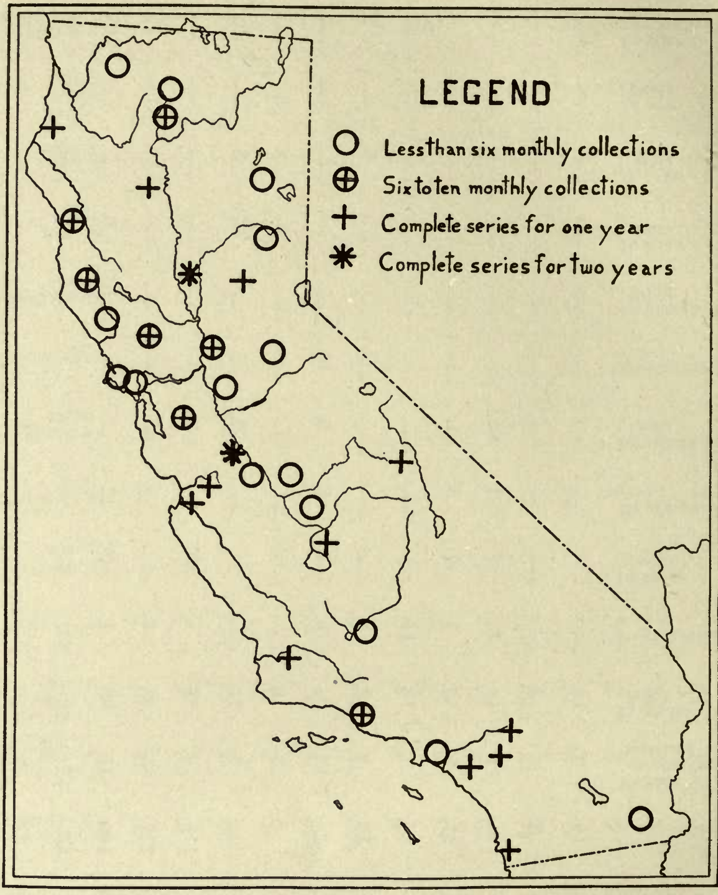


Fig. A.—Map of California showing localities in which collections of western meadowlarks have been made for the purpose of stomach examination. A complete series is a minimum of six birds collected each month in a year.

Table I, pages 416–417, gives a summary of the material available.

Examination of Stomach Contents

On removing the stomach (gizzard) and tag from the cloth, the stomach was carefully cut open, the incision being made with a scissors along the longest axis and through the muscles, starting at the cardiac opening, and the contents emptied upon a glass plate. Great care was taken to see that every bit of the contents was scraped from the walls of the stomach. A Zeiss binocular was used in examining and determining the material found. Where possible, counts were made of all vegetable and animal elements of food. The amount of mineral matter used as grinding material was computed by a calculation in per cent of the comparative volume.

The comparative volume of each kind of food was calculated in per cent of total volume contained in the stomach examined. In the estimation of apparent volume there is always a personal error. However, since this method is depended upon to furnish evidence as to the comparative amounts and not actual amounts, the personal error is largely distributed in the averages. Parts of insects and weed seeds used in identification were wrapped separately in small pieces of paper to prevent their mixing with the rest of the stomach contents.

Where possible, the heads of insects were used as a safe criterion of the number eaten. In many cases dependence was necessarily placed on an enumeration of the mandibles. In the case of grasshoppers the mandibles are probably retained in the stomach longer than the soft parts, but experiment has shown that the stomach is completely emptied in four hours, so that it is necessary only to give a long enough period of digestion to make such an enumeration dependable. The fact that the mandibles of grasshoppers may be found along the entire length of the digestive tract also supports the view that this criterion is trustworthy. Beetles, bugs, bees, and ants were readily counted, because the heads and thoraces of these insects remain long undigested.

Partly digested grain and weed seeds were computed in percentage volume, but in addition the undigested kernels and seeds were counted.

Owing to the finely comminuted condition of the food to be found in the intestines, that found in the stomach alone was used as evidence of the food taken. The stomach alone gives the best unit of volume. The consideration of the food to be found in the intestines could at best but show evidence as to food for a longer time previous to the death of the bird.

In all cases the stomach contents were preserved in vials, so that verification of the results will be possible at any time. As a rule, the contents have been preserved by drying, but where certain animal matter such as larvae was present the material has been preserved in seventy per cent alcohol.

After each examination the kind and quantity of food was recorded on a stomach blank. Complete data were recorded on larger blanks. Summaries giving the results of the examinations of the different collections were made in the form of tables.

Identification of Stomach Contents

Collections of insects and seeds for comparison were most helpful in identifying the different insects and seeds. Insects and seeds, if in good condition, can be determined at least to the genus by this method. Floating out the wings of certain insects in water and the mounting of other parts in some clearing fluid are methods which have had to be resorted to occasionally.

In the examination of a large series of stomachs it is nearly always possible to obtain a fairly good specimen of an insect which is commonly taken as food, for some bird is usually found which has taken such an insect just before being killed.

Food of the Western Meadowlark in California

The food of the western meadowlark is made up of both vegetable and animal matter. The vegetable food is largely composed of grain and seeds. The animal food is made up largely of insects. The accompanying diagram (fig. B) shows the relative amounts of the different kinds of food taken during the year. A discussion of each kind of food is followed by a statement of the "amount destroyed" and the "economic importance."

Vegetable Food

Grain

Grain forms the largest percentage (seventy-five per cent) of the vegetable food for the year and makes up thirty and eight-tenths per cent of the total food for the year. But a small part (one per cent) of that found in the stomachs has been sprouted.

This was therefore in all probability pulled from the seeded fields. Oats is the grain most often taken. It is not only preferred, but is the most available. Much (about seventy per cent) of that found in the stomachs is wild oats (*Avena fatua*). This oat is so mixed with the tame varieties that part of it must be considered a loss to the rancher, for it makes good feed. Nearly half

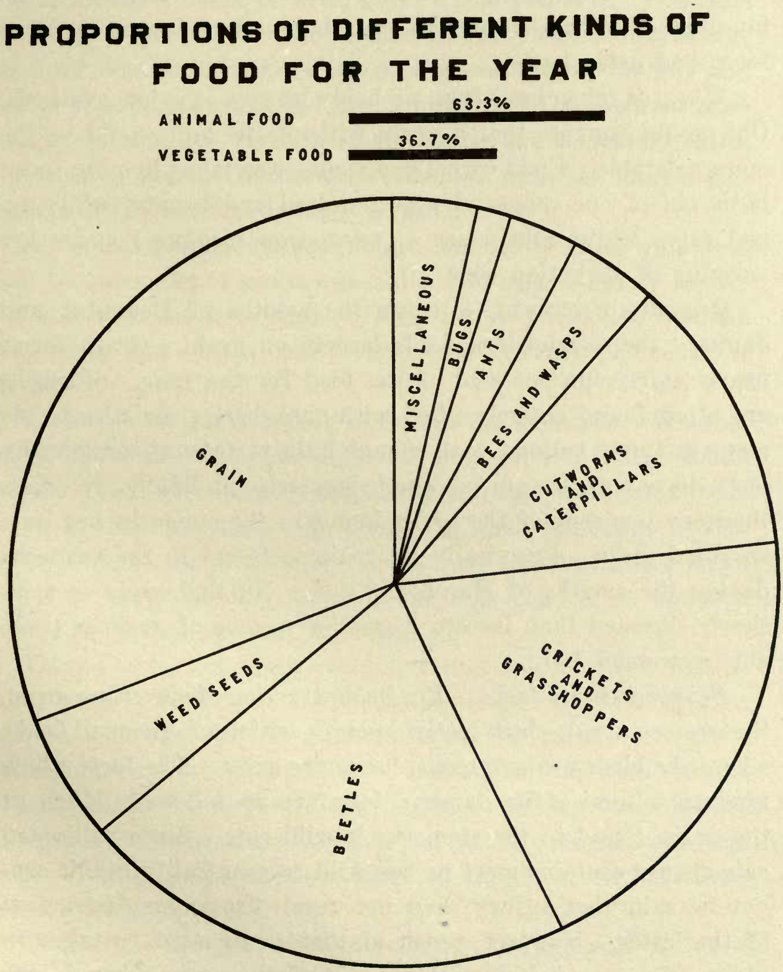


Fig. B.—Diagram showing relative amounts of different kinds of food taken during the year by western meadowlarks.

of all the grain taken by the birds examined was consumed during the three winter months—November, December, and January. It is apparent, therefore, that availability, lack of insect food, and possibly the sprouting condition of the grain are responsible for this. Owing probably to the feeding habits of the bird, mixtures of different grains are seldom found. The stomachs usually contained one kind of grain only.

Barley, because of its greater availability, is more often taken than wheat. The barbs are seldom found in the stomach. One hundred and fifty-five out of one thousand and nine hundred birds had eaten barley.

Wheat is taken less often, probably because it is less available. One would suppose that a grain without the hull would be the more palatable. Field corn (*Zea mays*) was taken by only seven birds out of one thousand nine hundred and twenty, while ten had eaten white milo maize (*Andropogon sorghum*) and other varieties of Egyptian corn.

Quantity destroyed.—During the months of December and January the meadowlark feeds largely on grain. Grain forms nearly thirty-one per cent of the food for the year. Stomachs are often found entirely filled with oats, barley, or wheat. As many as thirty kernels, with enough hulls to account for as many more, have been found in a single stomach (pl. 22, fig. 3). Less than one per cent of the grain found in the stomachs has been sprouted grain. Practically no grain is found in the stomachs during the months of March and July. In that grain is more slowly digested than insects, a smaller volume of grain is probably consumed daily.

Economic importance.—For its destruction of sprouting grain, the western meadowlark justly deserves criticism. In small fields, where the birds are numerous, losses are great. The facts which tend to minimize the damage done are as follows: Much of the grain found in the stomachs is wild oats. Since cultivated oats always contains more or less wild oats in California, it cannot be said that injury does not result from the destruction of the latter. However, much of that eaten must be taken in places where no injury results. All of the grain taken in the months of August, September, and October must be considered waste grain and of little economic importance. Meadowlarks are not known to attack heads of grain. Whatever field grain is taken is picked up from the ground. Damage done to sprouting grain can result only during a limited period of time (two weeks). After the second leaf appears no damage can result.

Weed Seed

Weed seed evidently forms the principal part of the vegetable diet of this bird where or when grain is not available. The seeds of such weed pests as tarweed, mustard, tumbleweed, Napa thistle, pigweed, amaranth, canary grass, Johnson grass, foxtail, and sunflower are consumed in large quantities. The seeds of such forage plants as the burr-clover and filaree are commonly eaten. The seeds of filaree (*Erodium cicutarium*) form the largest percentage of the weed seeds taken as food.

A stomach has seldom been found completely filled with weed seed, for some sort of grain, especially wild oats, is nearly always available with the weed seeds. Nevertheless during the late fall weed seeds make up a considerable part (twenty per cent) of the diet.

Grass has been occasionally found in the stomachs. Whether or not it was taken intentionally it is impossible to state. Small sprouts from sprouting grain and sprouting seeds have been found in some instances. As a rule the seeds appear to be separated from the large sprouts when eaten. Small pieces of straw and other vegetable fiber found in the stomachs can be classified as rubbish picked up with the food.

There has been a slight complaint that meadowlarks damage sugar beets by feeding on the sprouting seeds. Mr. F. J. McCoy, assistant manager of the Union Sugar Company, Betteravia, California, says on this point: "I have noticed meadowlarks in early spring in our beet fields, but noticed they were feeding on insects." Stomach examination has failed to disclose any beet seeds. The stomachs of birds collected in beet fields have been found filled with insects.

Quantity destroyed.—The maximum consumption of weed seed occurs in October, when nearly one-fourth of the food is made up of this kind of food. Weed seed amounts to five and three-tenths per cent of the food for the year. Over 150 seeds of filaree (*Erodium* sp.) have been taken from a single stomach. Tarweed, pigweed, tumbleweed, mustard, turkey mullein, Napa thistle, Johnson grass, canary grass, foxtail, sunflower, burr-clover, and nightshade seeds have been found in numbers ranging up to fifty. In some few instances stomachs have been found entirely filled with weed seeds. Western meadowlarks appear to feed upon weed seeds to a considerable extent during the time in which they are available. Most weed seeds do not mature until late summer and fall. After plowing begins they are no longer available in cultivated districts, except along fence rows and in uncultivated fields.

Economic importance.—The destruction of weed seeds must be considered of value to the agriculturist. Weeds even in small numbers take a toll in the grain field. The destruction of weed seeds accomplished by western meadowlarks must help to limit, in some measure, the number of weeds which grow in fields and fence rows the following year. Meadowlarks feeding in grain fields must destroy weed seed that would not otherwise be destroyed. Their habit of feeding on sprouting seeds increases their efficiency as weed-seed destroyers. Seeds eaten are digested. In no case have undigested seeds been found in excrement.

Fruit

No vegetable matter found in the stomachs has been identified as fruit. Grape seeds have been found in a number of cases and there is no doubt that western meadowlarks eat grapes to a slight extent. No serious complaint as to their depredations in this direction has been received. The stomachs of practically all of the birds collected in vineyards have been filled with insects, mostly beetles.

A systematic list of the grain and weed seeds found in the stomachs follows:

Grain
- Oats
- Barley
- Wheat
- Field corn (Zea mays)
- Sorghum (Andropogon sorghum subsp.)

Fruit
- Grape seeds (Vitis sp.)

Weed seed
- Gramineae (Grass family)
  - Andropogon sorghum halepensis. Johnson grass
  - Panicum sp. Panic grass
  - Chaetochloa glauca. Bristly foxtail
  - Chaetochloa viridis. Foxtail
  - Phalaris minor. Small canary grass
  - Avena fatua. Wild oats
  - Bromus sp. Brome grass
  - Lolium temulentum. Darnel
  - Hordeum sp. Barley grass
- Cyperaceae (Sedge family)
  - Carex sp. Sedge
- Polygonaceae (Buckwheat family)
  - Rumex sp. Dock
  - Polygonum sp. Knotweed
- Chenopodiaceae (Goosefoot family)
  - Chenopodium sp. Goosefoot pigweed
- Amarantaceae (Amaranth family)
  - Amaranthus graecizans. Tumbleweed
  - Amaranthus sp. Amaranth
- Portulacaceae (Purslane family)
  - Lewisia sp. Bitter root
- Ranunculaceae (Buttercup family)
  - Ranunculus sp. Buttercup
- Cruciferae (Mustard family)
  - Brassica nigra. Black mustard
  - Brassica sp. Mustard
- Leguminosae (Pea family)
  - Medicago hispida. Burr clover
  - Medicago arabica. Spotted medick
  - Melilotus indica. Yellow melilot
  - Melilotus sp. Sweet clover
  - Trifolium sp. Clover
  - Lupinus sp. Lupine
- Geraniaceae (Geranium family)
  - Erodium cicutarium. Red-stem filaree
  - Erodium sp. Filaree
- Euphorbiaceae (Spurge family)
  - Eremocarpus setigerus. Turkey mullein
- Malvaceae (Mallow family)
  - Sida hederacea. Alkali mallow
- Onagraceae (Evening Primrose family)
  - Oenothera ovata. Golden eggs
- Primulaceae (Primrose family)
  - Anagallis arvensis. Pimpernel

Boraginaceae (Borage family)
  Amsinckia intermedia. Amsinckia
  Amsinckia sp. Amsinckia
  Cynoglossum sp. Hound's tongue
Rubiaceae (Madder family)
  Galium sp. Bedstraw
Solanaceae (Nightshade family)
  Solanum sp. Nightshade
Compositae (Sunflower family)
  Lactuca scariola. Prickly lettuce
  Centaurea melitensis. Napa thistle
  Centaurea solstitialis. Barnaby's thistle
  Carduus sp. Thistle
  Hemizonia sp. Tarweed
  Helianthus annuus. Common sunflower
  Iva axillaris. Ragweed

Economic importance of vegetable food.—The destruction of sprouting grain means a loss of dollars and cents to the rancher. This loss is minimized somewhat by the limited time during which injury is possible and the possibility of protective measures. A much smaller loss can be attributed to the destruction of grain picked up in newly sown fields. Grain on or near the surface of the ground in seeded fields is of doubtful value, as it cannot be depended upon to furnish a strong, healthy plant. Much of the wild oats and some of the tame oats must be considered waste grain or uncultivated grain. Its destruction, in spite of its utility as feed, cannot be considered a direct loss in money value.

Practically all the other seeds destroyed are the seeds of weed pests. The destruction of the seeds of certain forage plants such as filaree could be considered a detriment if they were destroyed in large enough quantities to make any difference in the amount of forage available. This same plant is considered a weed in many places. Any destruction of the seeds of thistles, sunflowers, Johnson grass and like weeds must be considered a benefit.

Animal Food

Coleoptera (Beetles)

The most constant article of diet of the meadowlark consists of beetles. The habitat of the bird would forecast this fact. Ground-beetles (Carabidae, Tenebrionidae), click-beetles (Elateridae), and weevils (Rhynchitidae, Calandridae, Otiorhynchidae) form the largest per cent of this kind of food. Representatives of practically every family of the Coleoptera, however, have been found in the stomachs.

A systematic list of the beetles identified follows:

Cincindelidae
- Cincindela sp.

Carabidae
- Calosoma sp.
- Amara californica Dej.
- Amara conflata Lec.
- Calathus ruficollis Dej.
- Platinus bicolor Lec. (?)
- Harpalus pennsylvanicus Dej.
- Agonostoreus maculatus Lec.
- Pterostichus sp.
- Bladycellus rupestris Say
- Anisodactylus dilatatus Dej.
- Anisodactylus sp.

Staphylinidae
- Staphylinus tarsalis Mann.
- Creophilus villosus

Silphidae
- Silpha ramosa Say

Dermestidae
- Dermestes sp.

Erotylidae
- Languria sp.

Histeridae
- Saprinus fimbriatus Lec.

Buprestidae
- ———— ?

Elateridae
- Cardiophorus tenebrosus Lec.
- Anchastus cinereipennis Mann.
- Drasterius livans Lec.
- Drasterius sp.
- Megapenthes aterrimus Horn
- Dolopius lateralis
- Melanotus variolatus Lec.
- Limonius infuscatus Mots.
- Limonius canus Lec.
- Limonius californicus Mann.

Lampyridae
- Telephorus consors Lec.

Malachidae
- Collops marginellus Lec.

Scarabaeidae
- Aphodius subaeneus Lec.
- Aphodius granarius Linn.
- Aphodius rugifrons Horn.
- Hoplia sp.
- Cotalpa ursina Horn
- Ligyrus gibbosus De Greer

Dytiscidae
- Agabus lugens Lec.

Chrysomelidae
- Glyptoscelis albidus Lec. (?)
- Gastroidea sp.
- Diabrotica soror Lec.
- Disonycha sp.
- Chaetocnema sp.
- Microrhopala melsheimeri Cr.

Tenebrionidae
- Blapstinus gregalus Casey
- Blapstinus rufipes Casey
- Blapstinus elongatus Casey
- Coniontis subpubescens Lec.
- Coniontis viatica Esch.
- Eulabis pubescens Lec.
- Eurymetopon sp.
- Eleodes sp.

Meloidae
- ———— (?)

Otiorhynchidae
- Rnigopsis effracta Lec.
- Rhigopsis sp.
- ———— (?)

Curculionidae
- Sitones californicus Fah.
- Sitones sordidus Lec.
- Lixus perferatus Lec.
- Cleonus virgatus Lec.
- Centrocleonus near angularis Lec.
- Baris cuneipennis Casey
- Baris sp.

Calandridae
- Sphenophorus vomerinus Lec.
- Sphenophorus simplex Lec.
- Sphenophorus sp.

Quantity destroyed.—Beetles are taken every month of the year, and form 21.3 per cent of the total food. Stomachs have often been found filled with nothing but beetles. From twenty to fifty have been found in a single stomach.

Wireworms, the larvae of click-beetles (Elateridae), are taken in large numbers where they are available. As they are less often seen above ground than cutworms, it is only natural that they do not form nearly so large a percentage of the food for the year. The adult click-beetles are also taken (see pl. 24, fig. 8).

Economic importance.—Wireworms are injurious to the roots of plants. Damage by them to garden truck and pasture land is of common occurrence. The ability of the meadowlark to probe into and remove from the soil such insects increases its value as an insect destroyer. The destruction of wireworms must be considered a benefit of considerable importance, especially in meadow and pasture land.

By far the greater number of beetles taken as food are the common ground beetles (Carabidae). These beetles are often classified as beneficial insects, because they are supposed to feed on other injurious insects. Certain ones are predacious and are known to feed on fly and beetle larvae in California. Of the food habits of others little is definitely known, and we are justified in speaking of them as neutral, for they do practically no harm and are not known to do any particular good. Tiger-beetles (Cincindelidae) and carrion-beetles (Staphylinidae), eaten to some extent, must be numbered among the beneficial beetles destroyed. The meadowlark, however, does feed upon many injurious beetles, chief of which are click-beetles (Elateridae), pinacate beetles (*Eleodes* sp.), leaf-beetles (Chrysomelidae), snout-beetles (Otiorhynchidae, Curculionidae), and weevils (Calandridae). Among the leaf-beetles is numbered the destructive California flower-beetle (*Diabrotica soror*). This and other members of the family constitute some of the worst beetle enemies of our crops. Snout-beetles (curculios) and weevils (*Sphenophorus* sp.) are well-known pests of fruit and grain. The continual destruction of large numbers of these injurious beetles must be considered a decided benefit.

Orthoptera (*Grasshoppers and Crickets*)

Grasshoppers and crickets form a large percentage of the meadowlark's food during the summer and fall, making up as high as eighty-five per cent of the food in August. The species of grasshopper taken is the one most available. Practically all of the species found in the state are doubtless represented in the stomachs. The common cricket (*Gryllus*) and the Jerusalem cricket (*Stenopelmatus* sp.) are common articles of diet. Katydids (Locustidae), being less common insects and having a different habitat, are not taken so often.

A systematic list of the Orthoptera found in the stomachs follows:

Gryllidae
- Gryllus integer Scud.
- Gryllus pennsylvanicus Burm.

Locustidae
- (?) Macrocentrum sp.
- Conocephalus acutalus Scud.
- Stenopelmatus irregularis Brun.
- Stenopelmatus sp.

Acridiidae
- Cedipodinae
  - Camnula pellucida Scud.
  - Arphia sp.
  - Dissosteira spurcata Saus.
  - Conozoa behrensi Saus.
- Acridiinae
  - Oedaleonotus enigma Scud.
  - Melanoplus devastator Scud.
  - Melanoplus differentialis Uhler
  - (?) Melanoplus uniformis Scud.

Fulgoridae
- (?) Labia minor

Quantity destroyed.—Next to beetles, grasshoppers form the most important article of diet. Nearly fifteen per cent of the food for the year is made up of these insects. Parts of as many as twenty-six large grasshoppers (one inch or over in length) and fifty-eight small grasshoppers (one-half inch in length) have been found in a single stomach. The maximum amount of this food is taken in June, July, and August, the birds feeding almost exclusively on these insects during these months. The state over, some grasshoppers are taken by the meadowlarks every month in the year. The quantity taken closely parallels the abundance of these insects.

Crickets as well as grasshoppers are relished by the meadowlark. As many as fifteen pairs of mandibles have been taken from a single stomach, showing that at least fifteen common black crickets (*Gryllus pennsylvanicus*) had been eaten within four hours by that particular bird. Five per cent of the food for the year is made up of crickets. Wood crickets, better known as Jerusalem crickets (*Stenopelmatus* sp.), being less abundant than the common cricket, are less often taken as food.

Economic importance.—Grasshoppers can be classed as injurious insects. The extent of their damage can be traced to their abundance rather than to the presence of any particular kind of grasshopper. The species which most often become abundant enough to cause serious losses in this state are the differential grasshopper (*Melanoplus differentialis*), the pale-winged grasshopper (*Melanoplus uniformis*), the devastating grasshopper (*Melanoplus devastator*), and the valley grasshopper (*Oedaleonotus enigma*). All of these grasshoppers are destroyed in great numbers by the meadowlark. The more abundant these insects become, the more do these birds turn their attention to this kind of food. Where grasshoppers are abundant, meadowlarks have been found to average as high as fifty grasshoppers a day. (See Bryant, 1912d.) As a grasshopper destroyer, the meadowlark is unequaled by any other bird unless it be the blackbird, and then only because of greater numbers of blackbirds. As grasshopper outbreaks continue to ravage certain parts of the state each year, the meadowlark performs a service to agriculture that can hardly be overestimated, in that it helps to keep the insects down to normal numbers, so that losses do not result, and prevents greater losses by taking a greater toll at the time of an outbreak.

Crickets are usually classed as injurious insects. The degree of injury, as with the grasshoppers, depends largely upon their abundance. Since the species of crickets fed upon by the meadowlark feed almost entirely upon plants and are often destructive to grain, their destruction is to be desired by the rancher. This is especially the case with the Jerusalem cricket, which is very destructive to potatoes.

Lepidoptera (*Butterflies and Moths*)

The general law that birds do not eat butterflies to any great extent appears to hold good in the case of the western meadowlark. (See p. 481). However, the following dependable observation made by Mr. John G. Tyler of Fresno, California, also furnishes evidence of the fact that butterflies are occasionally, at least, destroyed. "While strolling along the road east of this city the writer noticed a field of alfalfa that was infested with yellow butterflies. A nearer approach revealed the presence of several meadowlarks, and I was so fortunate as to see one of these birds seize a butterfly and make way with it. I am not prepared to say that the victim was actually swallowed, but it was certainly captured and killed."

The larvae of butterflies and moths are common articles of diet. Cutworms and caterpillars form ten per cent of the food for the year, reaching a maximum in May and June, when they amount to nearly a third of the meadowlark's food.

Even hairy caterpillars do not escape destruction. In one instance the larva of the mourning-cloak butterfly (*Euvanessa antiopa*) has been found in the stomach. Smaller hairy caterpillars are of common occurrence. Both the larva and pupa of the sphinx moth have been taken from stomachs. Pupae do not form so important a part of the diet as do the larvae.

The only Lepidoptera positively identified follow:

LEPIDOPTERA (BUTTERFLIES AND MOTHS)

Noctuidae
- Peridromia sp.
- ———— (?)
- ———— (?)

Nymphalidae
- Eugonia californica (Boisd.)
- Euvanessa antiopa (Linn.)
- (?) Papilio sp.

Sphingidae
- (?) Phlegethontius sp.

Quantity destroyed.—Cutworms and caterpillars form about twelve per cent of the food for the year. The maximum quantity is taken in the months of March and April, when almost half of the food taken is made up of these insects. Many of the stomachs contained as many as twenty large cutworms or caterpillars. One bird collected at Red Bluff, Tehama County, contained sixty-six cutworms and over thirty small beetles (pl. 23, fig. 5).

Economic importance.—Cutworms and army worms can be classed as two very important pests in California. Garden truck and even trees are sometimes defoliated when these insects become numerous. The depredations of the grape cutworm are only too well known in the state. Caterpillars are vegetable feeders and are always classed as injurious. The destruction of these pests in very large quantities by the western meadowlark must cause a direct saving to the rancher and fruit grower.

Hemiptera (*Bugs*)

Stink-bugs (Pentatomidae) appear to be relished in spite of their excretions, for they are taken in large numbers. Squash-bugs (*Anasa* sp.) have been found in only a few instances. Negro-bugs (*Corimelaena*) form the only other important Hemiptera taken. Cicadas appear to be relished and often caught. Two stomachs have contained aphids (*Aphis brassicae*). The following Hemiptera have been identified:

Hemiptera (Bugs)

Jassidae	Coreidae
—————— ?	Corizus sp.
Aphidae	Alydus pliosulus
Aphis brassicae Linn.	Anasa sp.
Membracidae	Pentatomidae
Stictocephala franciscana Stal.	Podisus pallens Stal.
Cicadidae	Podisus sp.
Platypedia areolata Uhl.	Euschistus conspersus Uhl.
Platypedia minor Uhl.	Euschistus servus Say
Reduviidae	Corimelaenidae
—————— ?	Corimelaena sp.

Quantity destroyed.—The commonest true bugs destroyed by western meadowlarks are stink-bugs (Pentatomidae), negro-bugs (Cormelaenidae), leafhoppers (Jassidae), and cicada flies (Cicadidae). They form nearly two per cent of the food for the year. As many as twenty stink-bugs have been taken from a single stomach. Negro-bugs are not taken in such large numbers, nor are they so abundant. Two stomachs have been found almost filled with leafhoppers, and many others contained two to ten of these insects. Cicadas, near relatives of the eastern seventeen-year locust, are occasionally taken, probably as often as they are available. Bugs form over three per cent of the food for the year.

Economic importance.—Most stink-bugs are vegetable feeders and occasionally give trouble. Negro-bugs are troublesome on berries. In the destruction of these insects the western meadowlark is also conferring a benefit. Leafhoppers are injurious to plants, because they secure their food by sucking the juice of the plant. Any destruction of leafhoppers, however small, is of value. The cicada in California is not abundant enough to be of economic importance. It lays its eggs in the sapwood of plants and trees. Since these insects, if they became abundant, would cause trouble as does the seventeen-year locust of the east, their destruction is to be looked upon with favor.

Hymenoptera (*Ants, Bees, and Wasps*)

Ants appear to be taken irrespective of size or kind, for they are to be found from the smallest to the largest. The common red and black ants (*Messor, Pogonomyrmex*), field ants (*Formica*), and carpenter ants (*Camponotus*) are most abundant in the stomachs.

Ichneumon flies are taken in considerable numbers. Bees and wasps form a less percentage of the food made up of Hymenoptera. In but one or two cases was a bee definitely identified as a honey bee (*Apis mellifera*). Solitary bees (*Chrysis*) and even bumblebees (*Bombus californicus*) have been found. Cow-killers (Mutillidae) are occasionally eaten, although it has commonly been supposed that they were well protected from attack by their sting, hairy covering, and warning coloration.

For several reasons the Hymenoptera have been very difficult to identify. The finely comminuted condition of the insects has proved an almost insurmountable difficulty. The following only have been identified:

HYMENOPTERA (ANTS, BEES, AND WASPS)

Ichneumonidae
 ——————— ?
 ——————— ?
 ——————— ?
 ——————— ?
Mutillidae
 Sphaerothalma californica
 Sphaerothalma aureola
Apidae
 (?) Apis mellifera
Bombidae
 Bombus californicus Smith
Chrysididae
 Chrysis sp.

Vespidae
 Polistes aurifer Sauss.
 Polistes minor Beauv.
Sphegidae
 Ammophila sp.
Formicidae
 Formacinae
  Camponotus sp.
  Formica sp.
 Dolichoderinae
  Tapinoma sessile Say
 Myrmicinae
  Messor andrei Mayr.
  Pogonomyrmex californicus Buckley
  Pogonomyrmex sp.

Quantity destroyed.—Bees and wasps form 3.6 per cent of the yearly food. In no case have ichneumon flies, which are valuable parasitic insects, been taken in numbers, five being the maximum found in a single stomach. Their rapid flight probably prevents a greater toll being taken. Ants are often eaten in large quantities and form over two per cent of the food for the year. It is not an uncommon occurrence to find a stomach almost filled with ants. Over one hundred have been found in a single stomach.

Economic importance.—Most bees and wasps are considered beneficial insects. Ants are either injurious or neutral; few are beneficial. In the destruction of ichneumon flies the western meadowlark is destroying a valuable parasitic insect. The destruction of bees and wasps must also be reckoned as a count against the bird. However, the small numbers destroyed minimize greatly the real and the possible damage done. The destruction of most kinds of ants makes little difference one way or the other, owing to their abundance and scavenger habits.

Diptera (*Flies*)

A few members of the family Muscidae, a few flower-flies (*Eristalis* sp.) and crane-flies (*Tipula* sp.) and the pupae of syrphid flies (*Syrphus*) are the only representatives of the Diptera which have been found in the stomachs of western meadowlarks. The following have been identified:

DIPTERA

Eristalis tenax	Lucilia caesar L.
Tachina sp.	Musca sp.
Syrphus sp. ?	Tipula sp.

Quantity destroyed.—Flies do not constitute any important percentage (about one per cent) of the food for the year and when found have been in small numbers. A few green bottle-flies and other members of the same family are eaten, as are also flower-flies and drone-flies. Birds collected at El Toro, Orange County, during 1911 had eaten large numbers of the pupae of flower-flies (*Syrphus* sp.). Crane-flies (*Tipula* sp.) are not taken as often as it would seem they would be from their abundance. Evidence is at hand, however, that western meadowlarks feed largely on the larvae when they become abundant. Mr. W. M. Hughes of Madera, Madera County, has made the following report: "When I visited the tract of land affected, I found myriads of blackbirds and thousands of meadowlarks on the ground making small holes into the ground at the roots of the plants and taking out the worm. Several hundred acres of fine crop was destroyed before the birds collected in numbers sufficient to destroy the pest." The outbreak referred to was in the vicinity of Minturn, Madera County, in 1909. Several hundred acres of barley were destroyed by crane-fly larvae at this time.

Economic importance.—In spite of the fact that the larvae feed upon decaying matter, most flies are considered pests because some of them carry germs of disease. Green bottle-flies are disease carriers. The larvae of flower-flies feed upon plant lice and hence are considered beneficial. The larvae of crane-flies, on the other hand, are destructive to vegetation. The small numbers of flies taken and the fact that injurious as well as beneficial forms are eaten make the destruction of Diptera by meadowlarks of little consequence.

Arachnida (*Spiders*)

Quantity destroyed.—Spiders and their egg-cases form less than one per cent of the food for the year. Most of the spiders taken are grass spiders (Agalenidae) and daddy-long-legs (Phalangidae), the commonest of those found in pastures. In no instance have more than two spiders been taken from the same stomach.

Economic importance.—Spiders should be considered as doubtfully beneficial or of neutral value to the agriculturist, in spite of the fact that they feed largely on insects. As a rule spiders are not abundant enough to be of great economic importance. Their destruction at the hands of the meadowlark is of no consequence, as the resulting effect on insect life is so small.

Miscellaneous Animal Food

Miscellaneous articles of diet form three and one-half per cent of the food for the year. The common sow-bug (*Porcellio scaber*) is the commonest crustacean found in stomachs. Two birds had eaten snails. Two birds from San Diego had each taken a scorpion. But few earthworms have been found in the stomachs. Centipedes (*Scolopendra* sp.) and millipedes (*Julus*) appear to form a constant part of the diet. They are evidently taken regularly where available. Two birds had eaten ant-lions (*Myrmeleon* sp.).

Quantity destroyed.—Centipedes, millipedes, scorpions, ant-lions, and sow-bugs may be considered oddities in the diet. Their slight availability may account in some measure for the small numbers taken by the western meadowlark.

Economic importance.—Of these miscellaneous elements in the diet, only millipedes and sow-bugs can be considered injurious. Centipedes are usually considered beneficial, scorpions injurious, and ant-lions of neutral value. None of these forms is taken in sufficient quantity to make their destruction either an injury or a benefit.

Inorganic Matter

Pebbles, used for grinding the food, make up the inorganic matter found in the stomachs. White and red pebbles, probably because of their conspicuousness, predominate. Pebbles appear to be necessary as an aid to the digestion of grain, but much less necessary for the digestion of insects. Pebbles are nearly always found with grain and weed seed, but seldom with insect food. Doubtless the chitinous parts of the insects largely take their place.

Two nestlings and two adults contained parts of egg-shells. It is a well-known fact that birds often eat the broken shells after the young have hatched. In one instance, at least, the parent birds had fed the young on the shells.

Principal Articles of Diet

The kinds of food forming a definite part of the food of the western meadowlark for the year are as follows:

Vegetable		Animal	
Grain	30.8%	Coleoptera	21.3%
Weed seed	5.3	Orthoptera	20.3
Miscellaneous	.6	Lepidoptera	12.2
		Hemiptera	1.7
		Hymenoptera	5.6
		Diptera	.1
		Arachnida	.2
		Miscellaneous insects	1.9

Examination of Feces

Other than stomach examination, the examination of feces would appear to give the best evidence as to the food of birds. That a considerable amount of knowledge concerning the food of meadowlarks can be obtained in this way is evidenced by the fact that the examination of feces of meadowlarks collected June 15, 1912, in the Berkeley Hills showed the following: Thorax of spider, heads of ants, mandibles and other parts of grasshoppers, wing covers and mandibles of beetles and pubescence from wild oats.

The examination of some feces collected from nestling birds at Lathrop, San Joaquin County, showed that these same hard parts passed through the digestive tract undigested. Consequently this affords a practical method of determining the kind of food taken. Its value as a means of determining the amount of food is much less, for only the more resistant parts can be found.

II.—Average Percentage-Volumes of the Different Kinds of Food of the Western Meadowlark

County	Year	Number of birds	Number of months	Grain	Weed seed	Beetles (Coleoptera)	Crickets	Grasshoppers	Jerusalem crickets (*Stenopelmatus* sp.)	Cutworms and caterpillars	Bugs (Hemiptera)	Bees and wasps (Hymenoptera)	Ants	Spiders (Arachnida)	Miscellaneous	Total animal food	Total vegetable food
Humboldt	1911	69	10	30.5	.7	36.9	.8	9.7	......	15.5	.2	2.7	.5	.8	1.2	68.6	31.4
Siskiyou	1911	30	8	28.4	1.6	28.4	.6	12.9	.2	16.2	3.4	3.9	.9	.2	2.8	69.6	30.4
Mendocino	1911	72	7	36.7	4.0	26.2	1.0	15.3	.9	6.6	2.5	5.0	.3	.4	.6	59.3	40.7
Sonoma	1911	20	3	45.8	4.9	7.3	1.4	22.2	1.0	15.4	......	......	.2	......	1.3	48.9	51.1
Tehama	1911	159	12	25.5	10.6	8.4	.3	28.1	......	15.4	2.5	1.5	3.6	.2	......	65.0	35.0
Sutter	1911	63	11	46.3	9.1	7.1	.6	27.3	......	6.4	7.6	4.2	.4	.2	......	49.3	50.7
Sutter	1912	42	7	25.8	6.2	22.0	13.8	8.0	......	9.4	2.0	4.7	.7	1.2	4.9	66.1	33.9
Plumas	1911	3	1	95.0	......	5.0	......	......	......	......	......	......	......	......	......	5.0	95.0
Nevada	1911	18	2	73.9	7.1	7.5	......	2.0	2.5	6.6	.1	......	......	......	......	18.9	81.1
Napa	1911	29	8	53.8	7.9	10.8	2.9	4.5	.8	8.6	.6	1.2	1.4	......	2.6	40.2	59.8
Sacramento	1911	24	6	15.2	13.4	29.0	.3	20.3	......	26.9	1.1	1.9	.8	.2	.4	70.9	29.1
Sacramento	1912	60	7	44.4	2.3	24.0	8.1	2.4	1.1	14.7	......	1.2	.4	.1	.6	53.2	46.8
San Joaquin	1911	31	6	9.6	2.7	21.4	18.1	18.0	.5	19.4	.1	.6	3.9	.05	1.6	87.3	12.7
Calaveras	1911	6	1	......	8.7	21.5	......	......	......	7.5	1.5	54.5	4.5	......	1.7	90.8	9.2
Alameda	1911	4	9	41.0	11.5	14.7	2.7	7.5	.3	14.1	.3	2.7	.5	.5	2.9	45.8	54.2
Stanislaus	1911	75	12	38.4	7.8	8.5	5.9	27.5	.5	3.7	5.3	.4	.4	.1	.2	53.5	46.5
Stanislaus	1912	72	11	32.3	2.0	9.9	5.7	42.4	......	1.7	1.3	.6	3.0	.1	.8	65.7	34.2
Merced	1911	94	6	3.9	.1	35.2	10.1	25.2	.06	9.9	1.7	3.3	5.4	.5	3.6	95.7	4.3

II.—Average Percentage-Volumes of the Different Kinds of Food of the Western Meadowlark—*Concluded*

County	Year	Number of birds	Number of months	Grain	Weed seed	Beetles (Coleoptera)	Crickets	Grasshoppers	Jerusalem crickets (*Stenopelmatus* sp.)	Cutworms and caterpillars	Bugs (Hemiptera)	Bees and wasps (Hymenoptera)	Ants	Spiders (Arachnida)	Miscellaneous	Total animal food	Total vegetable food
Madera	1911	18	1	12.5	......	59.5	3.1	.5	3.8	7.6	......	1.1	5.1	......	6.2	90.3	9.7
Fresno	1911	3	1	......	......	31.3	29.3	8.0	......	......	......	8.0	15.0	......	8.3	99.0	1.0
Kings	1911	184	11	9.3	27.6	19.0	.6	16.7	2.1	11.4	1.1	1.2	2.6	.1	6.7	60.8	39.2
San Benito	1911	67	9	49.5	.3	18.8	18.2	7.0	......	.5	1.5	1.6	.4	.3	1.1	49.8	50.2
Monterey	1911	50	7	47.8	2.7	6.0	7.7	24.9	5.1	.9	10.5	1.3	.3	.5	3.3	48.2	51.8
Santa Barbara	1911	19	2	27.1	.05	45.2	3.9	3.4	.7	6.4	3.3	3.3	.4	.8	5.5	72.8	27.2
Inyo	1911	71	12	12.7	24.0	25.9	.9	19.3	.1	7.3	1.9	1.0	5.2	.04	2.9	63.0	37.0
Kern	1911	6	1	.1	......	36.3	......	8.3	......	47.3	.5	.6	.8	......	5.8	99.9	.1
Ventura	1911	44	6	36.9	3.5	28.4	4.0	......	.1	4.1	......	1.2	.2	......	6.6	39.5	60.5
San Bernardino	1911	110	12	26.9	6.5	27.6	1.2	7.4	.9	18.4	3.1	3.8	.7	.2	2.5	67.9	32.1
Riverside	1911	117	12	35.4	3.1	27.1	.4	13.0	4.5	24.0	1.7	1.7	5.7	.1	......	61.9	38.1
Orange	1911	169	12	31.1	.9	6.7	2.7	41.9	3.7	7.3	1.8	.9	.5	.2	2.5	69.8	30.2
San Diego	1911	138	12	43.4	2.6	19.2	4.5	7.5	2.2	7.8	4.4	1.3	1.2	.2	4.7	53.2	46.8
Imperial	1911	18	1	8.1	......	13.0	11.1	20	......	59.6	.3	.5	......	......	5.0	93.0	7.0
Miscellaneous	1911	16	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Totals and averages		1920		30.8	5.3	21.3	5.2	14.2	.9	12.2	1.7	3.6	2.0	.2	2.6	63.3	36.7

Quantity of Food

Three methods may be used in estimating the quantity of food in a bird's stomach. First, the articles found may be counted; second, they may be weighed; or third, they may be estimated by volume.

The first method, although important as giving an idea of the bird's economic value by showing the number of injurious insects or seeds destroyed, fails to take into account the difference in size of the different articles, and does not show the relative amounts of each kind. The second method has been generally disregarded because of its impracticability. The third or volumetric method allows of a balance of the inequalities of size, and best portrays "the ratios each element bears to the others."

By the numerical method, fifty ants would be placed against, say, six ground-beetles. A computation made by the percentage-by-volume method would doubtless show that these two kinds of food represented only three and twenty-six per cent, respectively, of the whole food. Hence the idea furnished in the first case (a ratio of 50 to 6) is a misleading one. Numbers of one insect cannot be balanced against the numbers of another insect. As each bird of the same species has a certain average stomach capacity, the ratio of each element to this average capacity gives the most accurate idea of the relative proportions of each kind of food.

Although the first and last methods have been those most often used heretofore, the second presents certain advantages (e.g., mathematical accuracy) which should not be overlooked. A combination of the numerical and the percentage-by-volume method has been used in the present work. The number of birds taking the different kinds of food offers further evidence as to their capacity for good or ill.

McAtee (1912) has pointed out that statements of numbers of individuals in stomachs has an interest in direct proportion to the bigness of the number. Believing this to be largely true, the maximum number of individuals found in the stomachs has here received emphasis. These maximum numbers should not be considered as averages.

It does not seem fair to compare the food of a species of bird of small size with that of one of large size without taking into account the bird's capacity. The degree of injury or benefit is largely dependent on the total amount consumed. In this investigation measurements in cubic centimeters of the stomach contents of a number of western meadowlarks have allowed the computation of the average stomach capacity. For male birds this average capacity is three cubic centimeters; for female birds it is two and one-half cubic centimeters. The average capacity is two and three-fourths cubic centimeters.

This method allows of some interesting computations of the capacity for good or harm of the western meadowlark. If there are twelve meadowlarks to the square mile, as there are in many places, these birds demand over one hundred cubic centimeters of food daily. This capacity, estimated in grain, means 2200 kernels, in grasshoppers 150 average-sized individuals, in cutworms 125 individuals, in ground-beetles 300, in ants 2500. As digestion is constantly going on, much larger numbers are in reality taken, as is evidenced by a count of the insects in a stomach. These numbers, therefore, are not even a minimum.

As pointed out (p. 412), the results of the experiments showed that meadowlarks must completely digest a meal inside of four hours. It was also found that grain takes longer to digest than do insects. Thus it can be seen that the food found in the stomach at any one time does not represent the total amount of food taken daily, but only about a third part of that consumed daily. Owing to the slower digestion of grain, the amount found in a stomach must represent more nearly one-half of the daily requirement.

Taking an average capacity of two and three-quarters cubic centimeters and considering that each bird fills its stomach at least three times a day, one hundred western meadowlarks must consume near a liter, or about a quart of food each day. If the food be grain it can be seen that the amount of destruction is considerable; if the food be insects it can be seen that meadowlarks take a large daily toll of insects. The same type of computation shows that a single western meadowlark must consume six pounds of food a year.

Some idea of the average numbers of the common insects, grain, and weed seeds destroyed at each meal by western meadowlarks can be obtained from the following tables, which were computed from the results of stomach examination of birds collected in Sacramento and Stockton, California. The average for the day is three times that for each meal.

Number of Common Insects, Grain and Weed Seeds Destroyed by Western Meadowlarks Collected at Sacramento, California

February to April, inclusive

	Grain	Weed seeds	Beetles	Cutworms and caterpillars	Grasshoppers	Bugs	Ants, bees, and wasps	Spiders
1	......	61	6	8	......	......	......	......
2	......	......	......	71	......	......	......	......
3	3	......	6	5	......	......	......	......
4	......	......	10	12	......	......	1	......
5	......	1	4	......	......	......	......	......
6	......	......	8	......	......	......	......	......
7	......	......	5	......	......	......	......	......
8	......	......	3	1	......	......	......	......
9	2	2	5	16	......	......	......	......
10	......	......	......	7	......	......	......	......
11	......	3	5	3	......	......	......	......
12	......	3	......	......	......	......	......	......
13	......	3	2	......	......	......	......	......
14	......	7	2	......	......	......	......	......
Totals	5	80	56	113	......	......	1	......
Av. per bird	3	6	4	8	......	......	......	......

September to November, inclusive

	Grain	Weed seeds	Beetles	Cutworms and caterpillars	Grasshoppers	Bugs	Ants, bees, and wasps	Spiders
1	......	60	2	1	1	......	......	......
2	......	61	......	......	1	......	......	......
3	......	155	1	1	2	......	1	......
4	1	65	4	......	2	2	6	1
5	2	37	8	22	2	5	1	......
6	......	3	......	......	11	......	......	......
7	......	200	2	......	1	......	2	......
8	......	93	2	......	......	......	......	......
9	25	80	......	......	......	......	......	......
10	......	180	2	1	......	......	1	......
11	......	15	1	......	10	......	1	......
Totals	28	949	22	25	30	7	12	1
Av. per bird	2.5	86.2	2	2.2	2.6	.6	1	......

NUMBER OF INSECTS TAKEN BY WESTERN MEADOWLARKS AT STOCKTON, SAN JOAQUIN COUNTY, CALIFORNIA

Number of birds	Date	Grain	Weed seed	Beetles	Crickets	Grasshoppers	Cutworms	Hemiptera	Hymenoptera	Ants	Animal	Vegetable
15	March-June, 1912	6	25	88	52	88	68	4	7	4	311	31
	Av. per bird	.4	1.6	5.8	3.4	5.8	4.5	.2	.4	.2	20	2.0
	Av. per bird per day	1.2	4.8	17.4	10.2	17.4	13.5	.6	1.2	.6	60.0	6.0

Few people have any realization of the great quantities of insects consumed by birds. For instance, if we consider that there is an average of one meadowlark to every two acres of available land for cultivation (11,000,000 acres) in the Sacramento and San Joaquin valleys and that each pair of birds raises an average of four young, each one of which averages one ounce in weight while in the nest and consumes half its own weight of food each day, it takes over 343½ tons of insect food each day to feed the young birds in the great valleys alone. The increased consumption of insect food due to nestling birds comes at a time when insects are most numerous, and so is instrumental in helping to prevent an undue increase of insects. As insects become injurious only when in maximum numbers, this increased consumption by birds is doubly important.

A conservative estimate of the approximate amount of the different kinds of food consumed by the average meadowlark in California during a year is as follows:

Grain	1¾ lbs.
Weed seed	½
Insects	2¾
Total	6

The fact that the western meadowlark eats both animal and vegetable food is a point in its favor. If it were exclusively insectivorous the bird could not exist in such large numbers because of the lack of insect food during part of the year. The consequent destruction of insect life would therefore be much smaller.

Certain species of birds when hungry will not only fill the stomach, but will continue eating until the gullet is also filled. This is often found to be the case with linnets and bicolored blackbirds. In no case, however, has the gullet of a western meadowlark been found well filled with food. At the most, the last insect taken before the bird was collected has been found in the lower part of the gullet.

Capacity for Good or Evil as Evidenced by the Number of Birds Taking the Different Items of Food

The percentage-volume method of estimating the proportion of the different kinds of food taken by a bird gives us the best idea of the relative importance of the different kinds of food in the diet of a given bird. However, the frequency of occurrence of the different items in the food, shown by a statement of the number of birds taking each item, furnishes additional evidence as to the capacity of a species for good or ill. The number of birds taking a certain kind of insect food can be regarded as an approximate index of the availability of that kind of food, and to a much less extent as an index of food preference if we consider insects as being evenly distributed and birds as being but slightly influenced by psychological processes. A nearer approximation can be obtained by multiplying the number of birds by the number of insects taken. In such a computation the number of insects taken is considered, as well as the number of birds taking the different elements of food. By this method the index of availability of crickets at Live Oak, Sutter County, was four in 1911, whereas this index was 6902 at Hollister, San Benito County, in the same year. By the same method of calculation the index of availability of grasshoppers was 2162 at Live Oak and but 1541 at Hollister. In the first case crickets were 1670 times as available at Hollister as at Live Oak, and grasshoppers 1.4 times more available at Live Oak than at Hollister. The following table gives a comparison of availability of the commoner insects as evidenced by indices of availability. Preference is here classed as a factor in availability.

III.—Western Meadowlarks—Numbers and Percentages of Birds Taking Different Kinds of Food

Total number examined 1920

	Oats	Barley	Wheat	Corn	Sorghum	Beans	Weed seeds	Grape seeds	Grass	Beetles	Crickets	Grasshoppers	Jerusalem crickets	Cutworms and caterpillars
Number of birds taking	670	155	112	7	8	5	488	18	25	1444	239	587	100	516
Percentage of birds taking	34.7	8.	5.8	.3	.4	.2	25.	.9	1.3	75.2	12.4	30.5	5.2	26.8

	Wireworms	Bugs (Hemiptera)	Cicadas	Ants	Bees and wasps	Ichneumons	Butterflies	Pupae	Flies	Fly larvae	Crane flies	Spiders	Spider egg cases	Centipeds	Millipeds	Sow bugs
Number of birds taking	8	259	15	322	370	25	9	76	33	15	5	72	25	6	8	10
Percentage of birds taking	.4	13.4	.7	16.7	19.2	1.3	.4	3.9	1.1	.7	.2	3.7	1.3	.3	.4	.5

V.—Actual Numbers and Percentages of the Different Kinds of Food Taken by Adult and Juvenal Meadowlarks

Number of birds		Grain	Weed seeds	Beetles	Crickets	Grasshoppers	Jerusalem crickets	Cutworms and caterpillars	Bugs	Bees and wasps	Ants	Spiders	Miscellaneous	Animal food	Vegetable food
50	Actual numbers taken by adults	11	15	210	16	210	1	50	80	11	49	9	......	......	......
50	Actual numbers taken by juveniles	......	14	207	26	263	3	92	71	27	73	......	......	......	......
50	Percentages taken by adults	2.8	.9	24.8	2.6	45.5	1.8	9.2	8.3	1.4	1.8	1.3	3.6	96.1	3.9
50	Percentages taken by juveniles	3.0	.3	20.7	2.9	38.8	1.2	17.6	5.0	2.0	4.6	......	6.1	95.7	4.3

INDICES OF AVAILABILITY OF COMMON INSECTS EATEN BY WESTERN MEADOWLARKS

Locality	No. of birds	Beetles	Cut-worms	Grass-hoppers	Crickets	Bugs	Bees and wasps	Ants
Live Oak, Sutter Co.	60	1,775	288	2,162	4	533	78	18
Hollister, San Benita Co.	60	4,307	7	1,492	6,680	197	265	35

The most available and the most popular food of the western meadowlark, if it may be judged by the frequency with which it has been found in the stomachs, is beetles. Seventy-five per cent of all the stomachs examined contained beetles (Coleoptera). Vegetable food in the form of oats is next in order of frequency, thirty-four per cent of the meadowlarks examined having taken oats as food. Grasshoppers, cutworms and caterpillars, and weed seeds were found in thirty per cent, twenty-six per cent, and twenty-five per cent respectively of the stomachs examined.

The accompanying table gives a summary of the number of times each article of diet was taken and the percentage of each article in the diet of the species. Attention should be called to the fact that a very large percentage (seventy per cent) of the birds taking oats took wild oats (*Avena fatua*) instead of the tame varieties. Consequently not more than ten per cent of the birds examined had taken cultivated varieties of oats.

Although the percentages showing the proportionate number of times each kind of food is taken to the number of birds examined differs from the percentages showing the proportionate volume of each kind of food, yet they parallel each other to a considerable extent. The accompanying table, giving only the principal articles of diet, shows this parallelism in the percentages.

IV.—PERCENTAGE-VOLUME AND PERCENTAGE OF WESTERN MEADOWLARKS TAKING DIFFERENT ELEMENTS OF FOOD

	Grain	Weed seed	Beetles	Crickets	Grasshoppers	Bugs (Hemiptera)	Ants	Bees and wasps	Flies (Diptera)	Spiders (Arachnida)
Percentage-volume	30.1	9.9	17.0	3.5	18.0	3.1	3.0	4.0	.1	.2
Percentage of birds taking	46.0	25.0	75.2	12.4	30.5	13.4	16.7	19.2	1.1	3.7

Food of Nestlings

Three methods are available for determining the food of nestlings; first, the rate of feeding may be determined by watching the number of trips made to the nest by the adult birds while feeding the young; second, the young birds may be made to disgorge their food; or third, the bird may be killed and the food in the digestive tract examined. The first method has not been used with any great degree of success because of the difficulty in approaching near enough to the nest to observe the feeding. The western meadowlark does not become accustomed to an intruder so easily as do other birds. The food observed in the bills of adult birds carrying food to their young has most often been cutworms or grasshoppers. One female bird, while feeding, persistently flew into an oat field and returned each time with cutworms. Another female bird was seen to catch three or four grasshoppers in her bill, and then fly to the nest.

Examination of the digestive tract of nestling birds has shown that they are fed very largely on cutworms, grasshoppers, and ground-beetles. The stomachs of two nestlings obtained from the same nest contained egg-shells. This is not an unusual occurrence, for nestling birds of other species are fed on the egg-shells. In no case was grain found in the stomachs, and in only a few cases were weed seeds found. Young birds doubtless need a larger quantity of food than adults. In almost every case the stomachs were average full or over. This means that each stomach contained nearly three cubic centimeters of food. Since it has been shown that young birds need over one-half their own weight of food each day, the birds when hatched must consume about one-fourth of an ounce a day, and when ready to fly about two ounces.

This increased consumption of insects due to the demands of young birds comes at a time when there are growing crops which need protection and when insects are most numerous, thus emphasizing the value of birds as balancers. The fact that meadowlarks show a greater preference for certain kinds of food while feeding the young enlarges their sphere of usefulness.

In spite of the fact that a certain amount of grain and weed seed is available, young nestling birds are fed almost entirely on insects. It would seem, therefore, that there is a certain preference for insect food shown at this time of the year. It is a well-known fact that many adult birds which feed on weed seeds feed their young almost entirely on insects. It seems safe to say, therefore, that the western meadowlark, when feeding the young, turns its attention to insects.

The accompanying table (Table V, p. 445) gives a comparison of the food of fifty juvenile and fifty adult western meadowlarks.

Variation in Kind of Food

The kind of food taken by the western meadowlark is dependent upon two *cycles,* the individual cycle and the environmental cycle.

The individual cycle includes such factors as individual taste, time of feeding, and the preference for a particular locality. In fact, all of the factors which depend upon the individual tastes or habits of the bird are grouped here. Whether an individual bird has a particular taste for a certain insect, it is impossible to determine without experiment. Since we find different individuals showing different characteristics, we can safely infer that each individual may show a slight preference for one kind of food above another. Then, too, the time during which the bird feeds has some effect upon the availability of certain kinds of food, so that we should naturally expect that the kind of food would be governed to some extent by the time the bird chooses for feeding. The particular locality frequented by the bird must also influence the kind of food taken. The food of a bird feeding entirely in a grain field would certainly show a slight variation from that taken by one living entirely in a pasture.

The environmental cycle takes into account the changes in the availability of insects and seeds, due to seasonal and climatic conditions. The maximum supply of weed seed is available during September and October. The maximum supply of insects is apparently available during May and June. Even the cultivation of land has much to do with the availability of certain kinds of food. Many weed seeds are easily obtained during September and October, which, after plowing begins, are hidden beneath the soil and so made unavailable. This helps to explain why birds feed so largely on grain during the winter months. Grain is far more available in cultivated districts at this time than weed seed.

In some localities even a daily cycle may be noted. Certain insects appear in larger numbers after the sun has warmed up the soil. Certain insects, such as cutworms, are found in greater abundance before sunrise. Thus we might naturally expect that birds collected early in the morning would have taken a larger percentage of cutworms than birds collected later in the day. Stomach examination has substantiated this as a fact.

The kinds of crops raised in any particular locality must also influence the kinds of food taken, for it changes their availability. For instance, the stomachs of several meadowlarks contained Egyptian corn and milo maize. Where this crop is raised to any extent the meadowlark doubtless occasionally turns its attention to this type of grain. In other localities where only oats and barley are grown these grains are the only ones available.

VI.—Percentages of Food of Meadowlarks Taken in Alfalfa Fields in the Vicinity of Hanford, California

	Animal matter	Vegetable matter	Number cut-worms	Per cent cut-worms	Number beetles	Per cent beetles	Miscellaneous
1	100	......	3	50	4	15	1 potato-bug
2	96	4	2	30	7	46	1 potato-bug, 1 bee
3	100	......	25	80	9	20	
4	98	2	......	......	1	6	1 potato-bug
5	100	......	5	65	2	12	1 fly, 3 ants
6	96	4	19	76	6	20	
7	100	......	9	60	7	20	10 ants
8	88	12	23	75	4	10	1 fly
9	85	15	1	10	7	75	
10	94	6	21	83	2	8	1 pupa
11	100	......	2	80	2	20	
12	100	......	1	16	10	76	1 fly
13	100	......	4	55	6	20	17 small flies
14	100	......	4	85	3	15	
15	17	83	2	10	1	4	1 ant
16	100	......	8	60	5	14	1 cricket, 2 ant-lions
Totals and averages	92.1	7.9	129	52.1	76	24.3	16.1

Stomach examination has clearly demonstrated the fact that birds collected in alfalfa fields consume much larger quantities of cutworms and caterpillars than birds collected in grain fields in the same general locality. The following table computed after the examination of sixteen stomachs of meadowlarks collected in alfalfa fields in the vicinity of Hanford, Kings County. California, clearly brings out the increased percentage of cutworms and caterpillars in the food taken by birds in such fields. Another table showing a comparison of the food of thirty-four birds collected in the above locality, but in different kinds of fields, brings out the same point.

VII.—Comparison of Food Taken by Western Meadowlarks Collected in Alfalfa Fields, Grain Fields, Orchards, and Vineyards

Averages of nine birds per month collected in March, April, and May, 1911, at Hanford, Kings County, California

Kind of field	Per cent animal food	Per cent vegetable food	Average number of beetles	Per cent beetles	Average number of cutworms and caterpillars	Per cent cutworms and caterpillars
Alfalfa	95.9	4.1	5.1	24.1	11.2	61.4
Grain	99.4	.6	9.4	58.5	1.8	21.0
Orchard	98.3	1.7	4.8	31.7	6.5	55.7
Vineyard	78.3	21.7	.1	5.0	7.0	42.0

Variation of Food According to Time of Year

Abundant data have allowed a comparison of the food of the western meadowlark by the hour, day, week, month, and year. Little change in *kind* of food can be noted from one time of day to another unless birds were taken in different localities. Nevertheless, the *quantity* of food found in the stomachs varies with the time of day. The maximum is found about nine o'clock in the morning, and the minimum from one to two o'clock in the afternoon. The same can be said of the food from day to day. A comparison of the food from week to week, however, shows considerable change.

The change from week to week (and the same can be said of the change from month to month) closely parallels the availability of the different articles of diet. Weed seed and waste grain are nearly always available during September or October.

Yet if enough grasshoppers and ground-beetles are available, the birds evidently take these in preference, for stomachs are more often found filled with insects than with weed seeds. The accompanying diagrams illustrate the great change in food habits from one time of year to another. It will be noted in each instance that the food of the western meadowlark is made up largely of insects during the spring and summer months and largely of grain and weed seeds during the fall and winter months. It is needless to point out that this parallels the availability of insect food, and to a less extent the availability of vegetable food. In that the percentage of animal food for the year is greater than the percentage of vegetable food, and since some insect is nearly always found in stomachs filled with grain

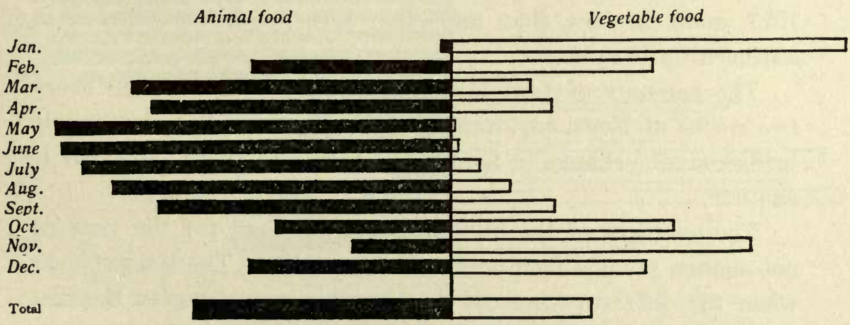


Fig. C.—Diagram showing change of food habits of the western meadowlark from month to month. Note that the maximum consumption of animal food is to be found in May, June, and July, and the minimum, corresponding with the maximum of vegetable food, in January and February. Computed from the results of stomach examinations of an average of twelve birds taken each month of the year at Red Bluff, Tehama County, California.

and weed seeds, whereas grain and weed seeds are far less often found in stomachs filled with insects, it seems safe to say that animal food is preferred and vegetable food is used as a makeshift.

The diagram showing the food of western meadowlarks collected in the vicinity of Red Bluff (fig. C) illustrates this preference for insects. Ninety per cent of the birds examined were collected in grain fields, and yet the only time when they turned to grain was in the winter, when the numbers of insects were at a minimum. Evidently grain fields furnish an abundant supply of animal food during most of the year. The maximum consumption of animal food is in June and the minimum in January. The minimum of animal food corresponds necessarily to the maximum in vegetable food.

The diagram showing the proportion of the two kinds of food of birds taken in the vicinity of San Bernardino (fig. D) lacks some of the inaccuracies to be noted in the former diagram. The maximum consumption of animal food is in April instead of May, due to the difference in climatic conditions. The birds taken in this locality, although collected largely in grain fields, consumed an unusually large proportion of animal food during 1911, more, in fact, than any other series of birds collected in southern California.

The amounts of food taken by meadowlarks collected every two weeks at Newman, Stanislaus County (fig. E), also clearly brings out the change in food habits from one part of the year to another.

The averages of the different kinds of food for the year do not change greatly from one year to another. The time of year when the different kinds of food reach a maximum in the diet

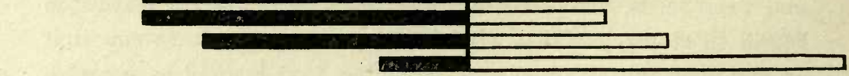


Fig. D.—Diagram showing change of food habits of the western meadowlark from month to month. Note that the maximum consumption of animal food is in April and May. Computed from stomach examinations of an average of six birds collected each month in a year at San Bernardino, San Bernardino County, California.

does change. This seems natural, for weather conditions affect the available food supply. Thus we find very few ants taken by meadowlarks collected at Newman, Stanislaus County, in 1911, but large numbers taken during the same months in 1912 (fig. E).

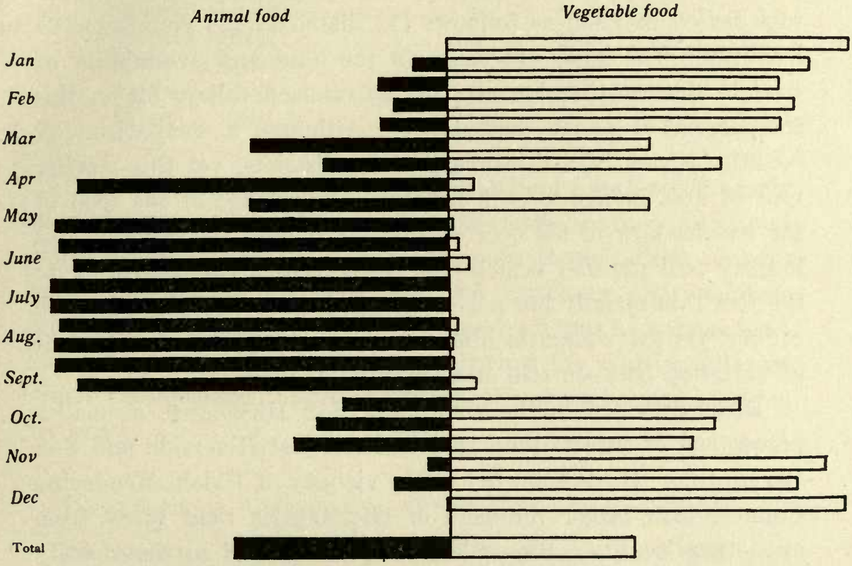


Fig. E.—Diagram showing the comparative amounts of the different kinds of food of the western meadowlark every two weeks during a year. Computed from the results of stomach examinations of birds collected at Newman, Stanislaus County, California.

The following table gives a comparison of the amounts of animal and vegetable food and the amounts of some of the common elements of food taken by meadowlarks at Newman, Stanislaus County, in 1911 and in 1912. The difference in amounts of animal and vegetable food is seven per cent. A large increase in 1912 of the number of grasshoppers taken can be noted. Seventy-two birds from each year were examined.

COMPARISON OF FOOD OF MEADOWLARK FOR TWO SUCCESSIVE YEARS

Year	Per cent animal food	Per cent vegetable food	Per cent grain	Per cent grass-hoppers	Per cent beetles	Per cent ants
1911	53.5	46.5	38.4	27.5	8.5	.4
1912	65.7	34.3	32.3	42.4	9.9	3.0

Variation of Food Habits According to Locality

The comparison of the food of the western meadowlark in California has been made in several different ways. As soon as it was found definitely that the food varied greatly from one part of the state to the other, it was decided to make three groupings for comparison as follows: (1) districts; (2) counties; (3) localities. The wide difference in the kind and availability of food in the coast region and in the interior valleys makes this comparison of prime importance. Although a comparison by counties covers in a measure that by districts, yet this smaller unit of area brings to each rancher a knowledge of the food of the meadowlark in his own county. Although the difference in locality will parallel largely the difference in county, owing to the fact that usually but one series of birds was collected in each county, yet this comparison affords a knowledge as to the amount of variation between still smaller units of area.

Birds collected in the vicinity of San Diego took a smaller percentage of insects than those collected at Riverside and San Bernardino. Birds collected in the vicinity of Ukiah, Mendocino County, took larger numbers of click-beetles than birds from any other locality. Stomachs of birds collected in the vicinity of Hollister, San Benito County, contained extraordinarily large quantities of crickets. At Hanford, Kings County, birds fed very extensively on cutworms. Birds collected at Newman, Stanislaus County, contained extra large percentages of stink-bugs and grasshoppers. Birds from Red Bluff, Tehama County, Live Oak, Yuba County, Sacramento, Sacramento County, Newman, Stanislaus County, and Los Banos, Merced County, took very nearly the same proportion of animal and vegetable food.

Variation of Food According to Districts

For the purpose of comparison the following county groupings were made:

Humid Coast Belt:	Humboldt, Mendocino, Sonoma, Marin.
Interior Valleys:	Tehama, Sutter, Sacramento, San Joaquin, Alameda, Merced, Stanislaus, Madera, Fresno, Kern, Kings.
Mountain District:	Shasta, Lassen, Nevada, Calaveras.
Arid Coast Belt:	Ventura, Los Angeles, San Bernardino, Riverside, Orange, San Diego.
Desert:	Inyo, Imperial.

The following table gives the food of the western meadowlark in these districts:

TABLE SHOWING VARIATION OF FOOD ACCORDING TO DISTRICTS

	Number of birds	Per cent animal food	Per cent vegetable food
Humid Coast Belt	99	59.0	41.0
Interior valleys	785	61.8	38.2
Mountain district	27	69.6	30.4
Arid Coast Belt	536	58.5	41.5
Desert	58	63.0	37.0

By considering only those localities where complete or nearly complete series were obtained, a still more marked difference could be noted. If the results from an examination of more birds from the humid coast belt and mountain districts were available, the results would show a larger amount of animal food. The remarkable thing is that, considering the widely different climatic conditions, the food averages do not vary more than ten per cent.

INFLUENCE OF AGE AND SEX ON QUANTITY OF FOOD TAKEN

As the male weighs an ounce (28.35 grams) more than does the female, a difference of one-half cubic centimeter in capacity is accounted for. Juveniles average less food than adults. This is explainable on the ground that they are less experienced in obtaining food. Male and female nestlings apparently have more nearly the same capacity than do adults of different sexes.

A slight variation has been noted between the food of adults and young birds, both in kind and quantity. Young birds apparently lack the experience of the adults and pick up only the more conspicuous insects and weed seeds. They also lack the experience needed for catching certain insects, and therefore the stomachs average a little less in volume of food. It has been pointed out by Finn (1887) "that each bird has to separately acquire its experience, and it well remembers what it has learned." There appears to be little instinctive knowledge of the different kinds of food, and each young bird must test and learn. It would seem, therefore, that young birds would collect many so-called protected insects, whereas some experienced ones would pass them by. This theory has not been supported by the results of this investigation, nor, on the other hand, has it been broken down. Although young birds were distinguished from adults, yet the unusual insects found were not constantly taken from the stomachs of young birds.

Combination of Field and Laboratory Work

Judd (1901) has suggested, as the best means of determining the food of birds, an examination of the available food supply combined with stomach examinations of birds taken in the same locality. There are many points which commend this method. Yet there is great difficulty in determining the available food supply. Even an experienced observer cannot estimate even with moderate accuracy the comparative numbers of insects and weed seeds in any given locality. A bird is able to see many articles of diet which such an observer doubtless overlooks. Let me cite a case in point: A meadowlark was seen to fly to a grain field and collect cutworms to feed its young. Careful investigation by me of the place where the cutworms were collected failed to reveal any. The same was noted with a pair of Brewer blackbirds who persistently collected cutworms in a pasture. Continued investigation in the same pasture did not allow of the collection of a single cutworm.

An attempt was made to follow this particular line of investigation, but was finally given up on account of the multitude of personal errors which are easily introduced. It seemed best to concentrate on the usual method of stomach examination, thereby making comparison with previous work possible.

Relation of Birds to Insect Outbreaks

The value of birds as insect destroyers is more noticeable at the time of an insect outbreak. Their importance in maintaining an equilibrium depends largely upon their effect when insects occur in abnormal numbers and thus become noticeably injurious. In two insect outbreaks investigated the western meadowlark was found to take a very active part in insect destruction.

During the spring and summer of 1911 the nymphalid butterfly *Eugonia californica* became very abundant in the northern part of the state. Since butterflies are seldom eaten by birds, the outbreak afforded a splendid opportunity to study the food habits of birds. Consequently an investigation was carried on during the latter part of August at Sisson, Siskiyou County, California, when these insects were in abnormal numbers.

Apparently because of the availability of the insect, several birds were found to be destroying butterflies. The Brewer blackbird (*Euphagus cyanocephalus*) fed on them almost exclusively, whereas the western meadowlark (*Sturnella neglecta*), western kingbird (*Tyrannus verticalis*), blue-fronted jay (*Cyanocitta stellari frontalis*), and Say phoebe (*Sayornis sayus*) took them sparingly. A comparison of the food of birds taken before the plague with that of birds taken while the plague was at its height showed that birds had varied their food habits and had taken advantage of the abundant supply of insect food in the form of butterflies.

Both observation and stomach examination showed the western meadowlark to feed on the butterfly (*Eugonia californica*). A lone meadowlark feeding with some Brewer blackbirds on the grass plot adjoining the station at Sisson was seen to run after several butterflies and to catch one. In the examination of seven stomachs, two contained butterflies. Fifteen and two-tenths per cent of the food taken by the five meadowlarks collected in August was made up of butterflies. All of these birds were taken in meadow or cut fields of wild hay where other insect life was abundant. Beetles and grasshoppers formed the bulk of the food.

Stronger evidence that birds turn their attention to the insect most available can hardly be found, for in this case we find a supposedly unpalatable insect becoming food for a number of species of birds. The United States Biological Survey, in the examination of more than 40,000 stomachs, has found but four records of birds eating butterflies, ''and one of these probably relates to the capture of a very recently emerged specimen, or to one torn from the pupa before emergence, as it was accompanied by a pupa of the same species.'' (See McAtee, 1912c.)

Whether butterflies are too active to be caught, or whether they are unpalatable because of odor or taste, are questions still awaiting an answer. In any case it can truly be said that butterflies, considering their abundance, are not taken as food in anywhere near the proportion that other insects are taken. That four of the larger common birds of the region should have fed upon these insects and that one of these should have fed almost entirely upon them is certainly significant.

It cannot be said that lack of other food caused these birds to turn their attention to butterflies, for many of the birds collected had either taken no butterflies or but one or two. The butterflies were not only conspicuous, but extremely abundant. Some idea of their numbers can be obtained when it is known that in damp places or along the banks of streams, where the butterflies had gathered to drink, as many as one hundred and fifty individuals were counted in one square foot. In order to estimate the numbers flying counts were made of the individuals passing between two fir trees about twenty feet high and standing about thirty feet apart. The counts for ten successive minutes between 4:40 and 4:50 P.M. on August 20, 1911, were as follows:

1st minute	105	7th minute	96
2nd minute	119	8th minute	102
3rd minute	130	9th minute	83
4th minute	102	10th minute	112
5th minute	134		
6th minute	100	Av. per minute	108

It can readily be seen, therefore, that butterflies were the insects most available at the time. The significant thing is that certain birds changed their food habits to meet the changed conditions. Birds collected in the same locality before the butterflies became abundant had taken no butterflies.

The investigation did not show that birds can be depended upon to control butterfly outbreaks, for the numbers taken compared with the actual numbers of the insects were insignificant. The fact that the birds attacked the insect at a critical time in its life-history—the adult stage when the death rate is at its minimum and the insect has the best chance of surviving till egg-laying—made the work of birds more important than if they had fed upon the larvae or pupae. However, any increased destruction at the time when insects appear in abnormal numbers must be considered a benefit.

Four out of the five birds found to feed on the butterflies are numbered among the birds whose usual food habits justly subject them to severe criticism from the farmer. Consequently the conclusion can be drawn that some of the birds noted for their depredations often become valuable insect destroyers at just the time when they are most needed as such.

This evidence fails to support Mr. McAtee's contention that "butterflies are in very little demand with birds in the United States." Nor, on the other hand, does it support the conclusions of Finn (1897) that "there is a general appetite for butterflies among insectivorous birds, even though they are rarely seen when wild to attack them." Middle ground seems to be the best position to assume until more evidence is at hand.

In our attempt to explain why butterflies are seldom taken by birds we have laid emphasis on palatability. This factor can at best be but one of many factors, many of which are perhaps just as important if not more important. Then, too, it should be noted that palatability is an extremely variable factor, for it varies with the species, the time of year, the availability of food, etc. We still need a full examination of all of the factors governing the food-taking of birds in order to explain the interrelation between birds and butterflies.

In an investigation of a grasshopper outbreak at Los Banos, Merced County, in July, 1912, it was found that western meadowlarks were destroying an average of nearly fifty grasshoppers a day. From point of numbers and average number of grasshoppers destroyed, the western meadowlark was, next to the bicolored red-wing, the most efficient destroyer of the pests. Meadowlarks averaged more grasshoppers per bird and were outdone by the red-wings only when the numbers of individual birds and the total destruction accomplished by each species were considered.

A comparison of the food of meadowlarks taken in the same locality in 1911, when grasshoppers were not so abundant as they were in 1912, demonstrated the fact that meadowlarks averaged more grasshoppers when these insects were abnormally abundant than they did when they were not so abundant. The results of stomach examinations follow:

Food of Western Meadowlark at Los Banos, Merced County, California

Number of birds	Date	Animal food	Vegetable food	Average no. of grass-hoppers per bird	Total per cent grass-hoppers
10	July 11, 22, 1911	99.0	1.0	7	83.1
5	July 15, 17, 1912	99.2	.8	16	96.2

Meadowlarks took very nearly the same percentage (99, 99.2 per cent) of animal food each year at the same season, showing that at this time of year the bird is almost wholly insectivorous. The availability of grasshoppers as a diet appears to have influenced the birds taken in 1912, for they averaged sixteen grasshoppers apiece as against seven taken by birds collected in 1911.

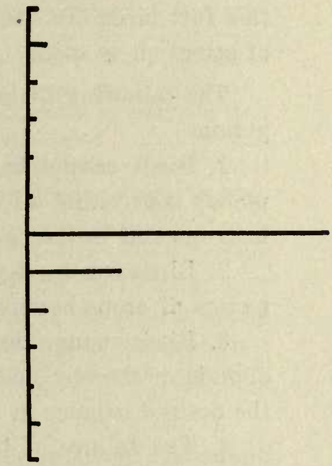
As the numbers of grasshoppers in 1911, compared with the numbers in 1912, is not definitely known, it is impossible to state whether these birds changed their food habits in response to the extreme availability of the insects in 1912. It is also impossible to state whether the numbers taken in 1912 were in direct proportion to the numbers taken in 1911 or whether they failed fully to respond to the change in insect population. The fact remains, however, that meadowlarks, and other birds as well, took greater numbers of grasshoppers when they were abnormally abundant, but also forsook certain articles of diet, such as beetles and weed seeds, thus causing an increased percentage of grasshoppers to be taken as food. The direction of the change of food habits was certainly coincident with the direction of change in food supply.

The efficiency of a bird as an insect destroyer at the time of an insect outbreak is governed more largely by the numbers of birds than by their individual capacity. This was conclusively shown in the investigation of the grasshopper outbreak. The comparative destruction of grasshoppers per day by single individuals and by the total number of each species is represented in the following table:

COMPARATIVE DAILY DESTRUCTION OF GRASSHOPPERS BY BIRDS

Species	Class	Average no. of grasshoppers per day by One bird	Average no. of grasshoppers per day by Total population
Anthony Green Heron	B	42	1,050
Kildeer	B	33	5.445
Burrowing Owl	A	84	1,260
Western Kingbird	D	8	1,280
Black Phoebe	D	9	180
California Horned Lark	D	8	88
Bicolored Red-wing	B	29	78,590
Western Meadowlark	B	48	24,720
Bullock Oriole	B	45	4,050
Brewer Blackbird	D	9	225
English Sparrow	D	2	100
Cliff Swallow	D	3	2,265
California Shrike	C	12	1,200
Destruction per square mile by total bird population			120,453

Relative destruction by different species represented by lines



Class A represents birds taking an average of over 50 grasshoppers per day; class B, 25–50; class C, 10–25; and class D, fewer than 10 grasshoppers.

The comparative numbers of the different species were calculated by averaging censuses taken and by using the average per mile as a multiplier. Although not accurate, the table nevertheless demonstrates the fact that such birds as the bicolored red-wing and the western meadowlark, birds of small capacity, because of their greater numbers, far outrank in efficiency birds with larger individual capacity.

The fact that the western meadowlark, or any bird, turns its attention to the insect most abundant only emphasizes its value as a balancer. If meadowlarks took no greater proportion of insects when they are in abnormal numbers than when they were in normal numbers, they would play a decreasing part in restoring a balance. Since they do change the proportions of food to meet the fluctuations in the number of insects, they must be considered an important factor in the restoration of normal conditions.

A great number of factors operating together determine the abundance of an insect. Birds and other natural enemies are but one of these many factors. The rate of reproduction and food supply are probably more important factors. In spite of this fact birds are one of the limiting factors and are deserving of attention as such.

The following facts have been demonstrated by these investigations:

1. Birds cannot be considered a dependable means of completely controlling all insect outbreaks, but can be inferred to be instrumental in the prevention of many.

2. Birds can be depended upon to act as defenders and protectors of crops because of their warfare against insect pests.

3. Birds change their food habits and feed on the insect most abundant, thereby making themselves important maintainers of the desired balance in nature.

4. The failure of birds to check an insect outbreak entirely is evident to all. Their success in preventing insects from becoming abundant is not so apparent, but is none the less real. All obtainable evidence points to the fact that the regulative influence exerted by birds when insects are to be found in normal numbers, though less apparent, is none the less important, for at such times artificial control measures are seldom used.

5. Birds, which on account of their abundance cause serious losses to the agriculturist, often become for the same reason the most efficient insect destroyers at the time of an insect outbreak.

6. Birds help to maintain an equilibrium in nature. Their destruction, therefore, causes a dangerous disturbance of that balance of nature most suited to mankind.

Verdict of Ranchers

In order that the opinion of the men most directly concerned might not be overlooked, a circular letter was sent out to prominent ranchers throughout the state. A copy of the letter follows:

Dear Sir:—

The State Fish and Game Commission has taken up the study of the meadowlark in its relation to agriculture and desires to know what you think of the bird. In order to secure comprehensive and uniform data, answers to the following questions are urgently requested:

1. Name ....
2. Address ....
3. Occupation ....
4. How many acres of land do you own? ....
   Is your ranch hilly upland or bottom land? ....
5. What is the principal crop raised? ....
   What other crops? ....
6. Has the meadowlark done any harm on your place? ....
   If so, how and to what extent? ....
7. Have you examined the stomachs of any meadowlarks to ascertain their food? .... If so, what was in the stomachs? ....
8. Approximately, how many meadowlarks are seen daily on your place? .... Are the numbers any greater when the grain is sprouting? ....
9. Do you prize the meadowlark as a song bird? ....
10. On the whole, do you consider the meadowlark a nuisance? ....

Any additional information that you can give on the subject will be appreciated. Address all communications to H. C. Bryant, Assistant State Fish and Game Commission, East Hall, University of California, Berkeley, California.

Over a hundred replies to this letter were received. Although the returns may be criticised on the grounds that a greater number of those interested in the bird because of its esthetic value sent in answers, yet care was taken to avoid this. Blanks were sent to the men who complained of the depredations of the meadowlark and to ranchers irrespective of their particular point of view. The average acreage of the men reporting was 638, so that it can be seen that the verdict is not from small land-holders or orchardists. Over ninety-eight per cent of those reporting grew grain or hay.

When the returns as to whether the meadowlark is a nuisance and as to whether it damages crops are classified as to counties the results are as follows:

County	Number reporting	Is the meadowlark a nuisance?		Does the meadowlark damage crops?	
		Yes	No	Yes	No
Siskiyou	5	......	5	......	5
Shasta	1	......	1	......	1
Humboldt	2	......	2	......	2
Trinity	5	1?	4	......	5
Mendocino	1	1	......	1	......
Tehama	3	2	1	2	1
Sutter	5	5	......	5	......

County	Number reporting	Is the meadowlark a nuisance? Yes	No	Does the meadowlark damage crops? Yes	No
Plumas	1	......	1	......	1
Butte	2	2	......	2	......
Yolo	1	1	......	1	......
Sonoma	4	4	......	4	......
Napa	2	1	1	1	1
Sacramento	2	1	1	1	1
Marin	1	......	1	1	......
Contra Costa	1	......	1	......	1
Alameda	7	2	4	3	4
San Joaquin	17	11	5	11	6
Stanislaus	2	......	2	......	2
El Dorado	1	1	......	1	......
Calaveras	1	1	......	1	......
Madera	1	1	......	1	......
Merced	3	......	2	1	2
Fresno	5	4	1	4	1
Monterey	9	2	7	2	6
San Luis Obispo	1	1	......	1	......
Kings	5	3	1	4	1
Tulare	4	1	......	3	1
Mono	3	......	3	......	3
Inyo	9	2	7	2	7
Kern	1	......	......	......	1
Santa Barbara	3	......	3	......	3
Ventura	......	......	......	......	......
Los Angeles	2	......	2	......	2
San Bernardino	1	......	1	......	1
Orange	5	......	4	......	5
Riverside	4	1	3	2	2
San Diego	2	......	2	......	2
Imperial	......	......	......	......	......
Totals	122	48	65	54	67
Total coast counties	31	5	25	5	25
Total central counties	60	35	19	38	22
Total northern California	105	47	50	52	52
Total southern California	17	1	15	2	15

It will be seen from this table that there is a considerable difference of opinion as to whether the western meadowlark damages crops. The astonishing fact is that many grain growers in the Sacramento and San Joaquin valleys report that western meadowlarks do not injure their crops, or that the injury is negligible.

The kinds of crops reported as being damaged ranged from garden truck, melons and grapes to corn and sprouting grain. Damage to garden truck, melons and grapes was reported by three or fewer men. Damage to oats was reported by over twenty, barley by less than this number, and wheat by less than ten. Most of the reports did not designate the kind of grain, simply stating that meadowlarks damaged sprouting grain. Answers as to the extent of damage varied from "none" to "total crop." The number of meadowlarks seen was reported as being from two or three up into the thousands. The answers to this question cannot be considered reliable. A large majority of those who considered the meadowlark a nuisance answered the question whether the meadowlark was prized as a song bird in the negative, whereas those answering the former question in the negative almost unanimously answered the latter in the affirmative.

Reports of damage were most numerous from the Sacramento and San Joaquin valleys. This seems natural, for grain is the crop most widely grown in this section and meadowlarks are most numerous. Southern California is most unanimous in its verdict of "not guilty." Two reasons can be made to account for this: the comparatively small amount of grain raised and the comparatively small number of meadowlarks. Few reports of damage have come from the northern coast region, in spite of the fact that meadowlarks are very numerous in this section.

The majority of those reporting have not had crops damaged by meadowlarks and do not consider the bird a nuisance. It does not seem reasonable to believe that all of these men based their report on sentiment. Evidence seems to point rather to the fact that many of those complaining of damage have based their judgment on circumstantial evidence and have somewhat exaggerated the real damage done.

A Determination of the Economic Status of the Western Meadowlark in California

Field investigation of the damage to crops has led to the following conclusions:

1. The western meadowlark is destructive to sprouting grain because of its habit of boring down beside the sprout and pulling off the kernel. The amount of damage varies with the location, the abundance of the birds, the time of year. the character of the soil, and the kind of grain. The damage to oats is greatest; wheat suffers less and barley little. A greater loss can be expected with broadcasted grain than with drilled grain, because not being sowed so deeply it is more readily obtained by meadowlarks. The real amount of damage done has evidently been overestimated, however, for fields apparently badly damaged have given the average yield later in the year. On the other hand, where meadowlarks are very numerous and the quantity of grain small, fields have had to be resown to assure a crop.

2. In the destruction of sprouting grain we have the only serious count against the meadowlark, for damage to melons, grapes and other crops has been found to be negligible. A number of things minimize the damage done, chief of which is the fact that meadowlarks are able to obtain the kernel for a limited period only. After the second and third leaves have appeared, the plant is well rooted and the loss of the kernel does not destroy the plant. Hence damage is limited to a period of about two weeks on any given field and is reduced by deep planting.

3. Those factors which make the depredations of the western meadowlark important and those factors which minimize the damage done may be summarized as follows:

1. Method of pulling sprouting grain.	1. Same method valuable in securing such insects as cutworms and wireworms.
2. Lack of insect food when grain is sprouting coupled with the availability of grain at the same time.	2. Take a larger percentage of insects than of grain during year.
3. Flocking habit.	3. Apparently driven to grain only when insects are not available.

4. Abundance of meadowlarks in grain-growing localities.
5. Great capacity and rapid digestion.

4. Time during which damage can result limited.
5. Flocking habit makes control measures easier.
6. Abundance of meadowlarks assures more efficient destruction of insect pests.
7. Great capacity and rapid digestion improves their value as insect destroyers; slower digestion of grain than of insects makes a less consumption of the former.
8. Do not destroy other crops.
9. A certain amount of thinning is sometimes desirable.
10. Often perform service in destroying insects in same field where damage was done.
11. Prefer uncultivated to cultivated land.
12. Unable to cause serious damage when grain is planted deeply.

4. A study of the life-history of the western meadowlark shows it to be a bird which prefers uncultivated to cultivated land, especially while feeding and nesting. It feeds in places where other birds do not feed, and takes many of the ground-loving insects which other birds do not take. Its habit of boring into the ground after food makes it important as a destroyer of such insects as cutworms, wireworms, and tipulid larvae, very destructive insects of the grain fields and meadows. Young birds are fed entirely on insects and need nearly their own weight of food each day. They demand the largest amount of food when insects are at a maximum. The western meadowlark appears to increase in numbers with cultivation of land when a proper food supply is furnished. It can be seen, therefore, that most of the facts regarding its life-history tend to place it among the beneficial birds.

5. Experimentation has shown that western meadowlarks, like other birds, have a very rapid digestion and are able to digest a full meal in four to six hours. Under these circumstances it is evident that they must consume large quantities of food. Ex-

perimental feeding has substantiated this fact. The larger the amount of food consumed the larger must be the toll taken. As experiment showed that insects are digested more rapidly than grain, proportionately larger amounts of insect food than vegetable food may be consumed daily.

6. Stomach examination has demonstrated the following facts: (1) A much larger percentage of animal food (sixty per cent) is taken during the year than vegetable food (forty per cent). The meadowlark feeds on grain to a considerable extent during the winter months. A very small proportion of that found in the stomachs was sprouted grain. A large proportion of the grain taken was made up of wild oats and had evidently not been gathered in grain fields. If meadowlarks by their depredations can drive many of the ranchers of the state to drill their grain and plant it more deeply they will be performing a service by increasing the yield. The increased yield so produced would doubtless more than cover the loss sustained from the birds.

(2) Western meadowlarks destroy large numbers of insects which are injurious to the same crop damaged by the birds themselves.

(3) The kind of food varies with time of year, locality, and abundance of available food. This correlation of food habits with the environmental conditions increases the bird's value as a balancer. If the meadowlark did not change its food with a change in supply, its value as an insect destroyer would be slight. In turning its attention to the food most abundant it becomes an important factor in maintaining a balance. Its survival as a destroyer of insects is dependent on its being able to obtain a supply of food when animal food is not available.

(4) The quantity of injurious insects taken daily is large enough to make this bird of at least some importance as a destroyer of insect pests. The cumulative effect of such destruction enhances the bird's value. Few beneficial insects are destroyed.

(5) The meadowlark destroys quantities of seeds of serious weed pests.

The service which birds render to agriculture has been overemphasized by those appreciating the esthetic value of birds.

Such writers have been prone to take the point of view that birds were expressly made to destroy injurious insects. One might just as well say that insects were created to furnish food for birds. If birds should become numerous enough actually to control the number of insects, they would doubtless become a greater pest than the insects themselves.

Parasitic insects are not proving to be the controls which their advocates have maintained they would be. And certainly there are arguments which prove that birds are not the panacea for all insect ills. Birds destroy many of the most beneficial insects known. Some of the most injurious insects are less often taken by birds. Birds, though they be in abundance, fail to prevent outbreaks of injurious insects. Birds scatter weed seed as well as destroy it. If there were no birds, would not other factors, such as parasitism, climatic conditions, etc., soon bring about a balance? Besides, cannot insect pests be more surely and successfully controlled by artificial means, insecticides, sprays, etc.? On the other hand, is there not a saving of expense in letting nature control insect ravages as far as possible?

All of these points deserve our consideration. They need to be weighed in the balance. When all the evidence for and against the utility of birds is in, a solution will be available. Until that time there will always be two sides to the question.

A partial solution of the problem is afforded by placing emphasis elsewhere, thereby avoiding these two opposing sides of the question. Forbes (1903) pointed out that the value of birds does not lie in the fact that they discriminate and take only injurious insects, but in the fact that they eat insects. The place filled by birds in the economy of nature is the important thing.

Most life under the natural order of things is conditioned very largely by its food supply: in the case of purely insectivorous birds, by insects; in the case of insects, by plant life. If it be true, as it appears to be, that organisms become so adjusted to their food supplies that only the surplus or excess is normally taken, then the importance of birds in their relation with insects lies in their toll of the surplus. Since it is the excess or abnormal abundance of insects that makes most trouble for the agriculturist and horticulturist, any factor, even though it be one of many factors, is important in insect control. Birds destroy insects; they are therefore a natural factor in the control of insect life. Since they do not fluctuate in numbers so greatly as do parasitic insects, they are a more constant factor than parasites. Insectivorous birds feed on the insect most abundant, hence they are the more important in limiting the numbers of insects. The proportion taken apparently varies directly as the numbers of the insects. The greatest toll on insect life comes during the nesting season, a time when the insect population is at its maximum. This in itself establishes the fact that birds have a real and an important part to play in the interaction of organisms.

Almost all insects are potentially injurious. Injurious insects in small numbers cause practically no damage. Neutral and beneficial insects in large numbers may become injurious. Hence the destruction of neutral and beneficial insects, if they are potentially destructive, may become at times of utility.

Insects have in turn adapted themselves to the constant drain on their numbers. This becomes very evident when we study the rate of reproduction of insects. However, it is the balance we need. Birds and insects both have a part to play in the balance. They are supplementary and indispensable.

This is an important viewpoint. Emphasis on the relation of birds to insects viewed from the standpoint of the interaction of organisms is rightly placed. Birds are important because they evidently are an indispensable factor in maintaining an equilibrium of organic life. If all birds play this important part, the destruction of any particular species of bird means a disturbance in the balance. The nearer man adjusts organic life to his desires the more important will become each natural factor concerned. Artificial means of adjustment often lack the efficiency of natural means.

It is readily acknowledged that birds are not the only checks on the increase of insects. The very large toll taken by them, however, places them in the front rank as insect destroyers. Parasites can become abundant only when their host becomes abundant and do their work effectively only after the insect has had sufficient time to cause damage. Birds in order to keep alive must wage a continual warfare on insect life, no matter what the abundance. They are evidently, therefore, to be relied upon as more dependable regulators than parasites.

Since, as has been shown, the average adult western meadowlark destroys nearly three pounds of insects each year and probably almost as many more pounds while feeding its young, its value to the agriculturist is apparent. The ratio of value of one of these birds living to that of one dead is, therefore, as five pounds of insects and one-half pound of weed seeds are to one and three-fourths pounds of grain, a considerable portion of which is made up of wild oats and waste grain.

The fact that the western meadowlark destroys certain beneficial insects cannot be counted a point in its favor. And yet the quantity taken is so small, less than five per cent of the food for the year, and the destruction so caused is such an indirect injury, that the damage possible is very slight and practically negligible. The destruction of one ichneumon-fly compared with the destruction of one hundred grasshoppers, somewhat the proportion in which they are taken, leaves no doubt as to the comparative benefit.

Since the western meadowlark feeds to a large extent on grass-land insects, many of which are not eaten by other birds, it must be considered a friend of the dairymen and grain growers, and not an enemy. ''The laborer is worthy of his hire.'' The grain taken by western meadowlarks can well be considered the pay for their efficient work in destroying injurious insects and weed seed.

It must be apparent from these comparisons that the balance is certainly in favor of the meadowlark. Birds are considered a national resource and so belong to the people as a whole. It seems doubtful whether the grain grower should destroy birds destroying his crops when the same birds might be performing a great service in destroying injurious insects in his own or his neighbor's alfalfa field.

This investigation has shown that the western meadowlark, as a rule, deserves protection and encouragement at the hands of the agriculturist. Only in rare cases can it be said that the bird does more harm than good. One and three-fourths quarts of insects taken by a western meadowlark during a year more than pay for less than one quart of grain, a large part of which does not represent a loss.

Although emphasis has been laid on the dollar and cents value, yet the other values which cannot be reckoned on the money basis must be taken into account. And here we find an even stronger defense of the western meadowlark, for the esthetic and scientific values greatly strengthen the case for the bird, in spite of the fact that these values are often unacknowledged by many who profit by them.

The investigation has shown that for the following ten reasons the western meadowlark should remain a protected non-game bird.

TEN REASONS WHY THE WESTERN MEADOWLARK (*STURNELLA NEGLECTA*) SHOULD BE A PROTECTED NON-GAME BIRD

1. As a destroyer of cutworms, caterpillars, and grasshoppers, three of the worst insect pests in the State of California, the western meadowlark is probably unequaled by any other bird. The stomachs of meadowlarks examined have averaged as high as six cutworms and caterpillars, and sixteen grasshoppers apiece. Maximum numbers of sixty-six cutworms and of thirty-two grasshoppers have been taken from a single stomach. As the time of digestion is about four hours, three times the average must be consumed daily. Other injurious insects destroyed are click-beetles, the larvae of which are wireworms, May beetles, weevils, crickets, Jerusalem crickets, stink-bugs, flies, and crane-flies. Fifty-nine and six-tenths per cent of the food for the year is made up of animal food. Each meadowlark in the state consumes, at the least calculation, six pounds of food each year, two and three-fourths pounds of which is made up of insects, most of which are injurious to crops.

2. The western meadowlark destroys a very small percentage of beneficial insects. That one hundred grasshoppers are destroyed to every parasitic ichneumon-fly is a very conservative estimate.

3. But one crop is attacked, for the only serious loss occasioned by the western meadowlark is to sprouting grain. Damage to fields of sprouting grain can be largely prevented by certain protective measures, some of which have been proved by experiment to be instrumental in producing better crops. Hence injury to crops is not only limited but largely preventable.

4. The western meadowlark destroys the seeds of some of California's worst weed-seed pests. During the fall months, when insects are not available, this bird destroys large quanties of weed seeds. Over two hundred weed seeds have been taken from a single stomach. Napa thistle, Johnson grass, canary grass, foxtail, tarweed, pigweed, tumbleweed, mustard, turkey mullein, sunflower, and nightshade are among the weed pests destroyed.

5. The western meadowlark, by feeding in places not frequented by other birds, procures many injurious insects which would not fall prey to other animals. In so doing it fills a niche in the economy of nature which apparently is not filled by any other form of life.

6. Investigations of the relations of birds to insect outbreaks have demonstrated that the western meadowlark, by turning its attention to the insect most available, becomes important as a maintainer of a balance of insect life. As such it becomes a defender and protector of crops.

7. The western meadowlark has great esthetic value. A bird of the meadow and pasture, it adds life and interest to treeless areas. Its bright colors and beautiful song have made it one of the best known birds in the state. The meadowlark even adds to the value of suburban real estate.

8. The western meadowlark cannot be considered a game bird. The following quotation is from an article by D. G. Elliott (1864), entitled "The Game Birds of the United States": "Not indeed every feathered biped, which a high breed of dogs will instinctively point, can be included in our list; for the meadowlark (*Sturnella magna*), that troublesome pest of every true

sportsman, whose dog, unless taught otherwise, will surely follow, has fairly no claim to this title, any more than have a snake or a turtle, to either of which a point will generally be made, and these last, it is hardly necessary to add, are neither birds nor game." In some of the eastern states, where the meadowlark is still unprotected, a parasitic worm often found in the small of the back deters many experienced persons from using the bird for food. The western meadowlark cannot be considered a game bird under the definition of such birds given in Section 637a of the Penal Code of the State of California.

9. By a decision of the United States Supreme Court (Geer v. Conn., 161 U. S. 519), birds are considered a national resource belonging to the people as a whole. The destruction of the western meadowlark by the grain grower causes a loss to the growers of alfalfa and other crops who profit enormously by the destruction of insect pests by the bird.

10. In certain sections of California, notably southern California, because of the small numbers of meadowlarks or owing to the kind of crops raised, the western meadowlark causes no damage and is considered distinctly beneficial. The extent of damage varies with the locality and the kind of crop raised.

Suggestions for the Protection of Crops

In a study of this kind something should be said as to the methods of protecting crops from the depredations of the western meadowlark, for, although we may in general say that the bird is highly beneficial to agricultural interests, yet local conditions and an overabundance of birds may demand protective measures. Scarecrows have proved inefficient as a means of protecting grain fields from attack by meadowlarks. The birds soon become accustomed to any object placed in the field, and so continue their depredations. Frightening the birds by shooting is found to be a better means, but is not always practical. It should be remembered that the protective measures suggested are all practical ones, for it has been shown that the damage is limited to two weeks; also that a certain amount of thinning is allowable, and in some cases of value. The outlay of several extra sacks of grain can be more than counter-balanced by the efficiency of the meadowlarks later in the year when injurious insects have become abundant in grain fields.

Where losses to crops warrant protective measures the following are proposed:

1. Plant grain deeply. It assures a better crop regardless of losses due to meadowlarks. Drilled grain gives a better yield than broadcasted and is also better protected from the attack of meadowlarks.

2. Fields bordering pasture or uncultivated land, if sowed more heavily along such margins, will usually be assured a normal crop.

3. Meadowlarks are easily frightened from a field by the noise of shooting or by a dog. As damage is limited to a short period of time, this method seems practical on small fields.

Recommendations as to Legislation

The United States Supreme Court (Geer v. Conn., 161 U. S. 519) has ruled that all game and wild birds belong to the people. The decision of the court in a test case in California is as follows: "We take it to be the correct doctrine in this country that the ownership of wild animals, so far as they are capable of ownership, is in the State, not as a proprietor, but in its sovereign capacity as the representative and for the benefit of all its people in common (State v. Rodman, *l. c.*). Consequently the people, through their various legislatures, control this natural resource. It is evident, therefore, that as in other things, the majority rule. In legislation the rights of the many are often clouded over by the activities of the few. Sometimes this is due to inactivity on the part of the many; sometimes it is due to a lack of knowledge on the part of the many and an accurate knowledge by the few. In the case before us we desire that there shall be no lack of information on either side.

The desire on the part of certain ranchers of the state to place the western meadowlark on the unprotected list in the hope that it might be so reduced in numbers as to prevent injury to crops, and the desire of certain sportsmen to add this bird to the list of game birds, has twice occasioned the introduction of a bill into the State Legislature. The same influences caused the Fish and Game Protective Association in 1912 to recommend placing this bird on the game list. In spite of the failure of the former bills to pass, protest has continued. As a final solution of the problem this investigation was ordered by the State Fish and Game Commission.

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This investigation having been completed and dependable data being at hand, the following considerations appear to the writer to demand the accompanying recommendation for legislation:

The western meadowlark (*Sturnella neglecta*), along with other birds, must be considered an important resource of this state, and therefore cannot receive destruction at the hands of some without distinct loss to others.

The western meadowlark can in no way be considered a desirable game bird, but must be numbered with the insectivorous non-game birds.

The western meadowlark, through a thorough scientific investigation lasting over a period of over two years and including field study and an examination of nearly two thousand stomachs, some being collected each month of the year in over twenty different localities in California, has been shown to be distinctly beneficial to agricultural interests as a whole and thus to all the people of the state.

The western meadowlark has an esthetic value greater than that of almost any other bird in the state. This value, although not capable of expression in dollars and cents, is nevertheless real.

Sufficient protection from the depredations of the western meadowlark is afforded the farmers of the state through a law providing for the "killing of a meadowlark, robin, or other wild bird by the owner or tenant of any premises, where such bird is found destroying berries, fruit or crops growing on such premises."

For these reasons, *the western meadowlark* (*Sturnella neglecta*) *should be retained on the list of protected non-game birds of the State of California and should at all times be afforded the protection it merits.*

SOME INTERESTING SIDE-LIGHTS ON THE INVESTIGATION

In an investigation of this kind where so many birds of the same species have come to hand it would be unfortunate if some account were not taken of certain scientific problems such as variation, parasitism, etc.

Parasitism

Owing to the fact that birds were received in the laboratory preserved in formalin it has been impossible to examine them for blood parasites. The only parasites discovered have been nematodes (*Spiroptera* sp. ?), which have been found in the body cavity and more often in the intestine. Fewer than one one-hundredth of one per cent of the birds examined, however, were found to be infected. Hence western meadowlarks do not appear to be parasitized to any great extent by round worms. Western robins have shown a larger percentage of infection.

T. G. Pearson (1909) says of the eastern meadowlark: "A parasitic worm often found in the small of the back deters many experienced persons, however, from pursuing the bird persistently." Whether the western meadowlark is parasitized to a greater or less extent is not known, owing to the lack of data on the eastern meadowlark in this regard.

Tachinid larvae have been taken from the stomachs of meadowlarks. As these larvae are common parasites of grasshoppers and crickets, their presence in the stomachs would seem to be easily explained. However, in two cases at least they were eaten separately, for no grasshoppers or crickets were found in the stomachs containing the larvae.

Malformation

Three or four birds received in the laboratory had lost a foot or leg. In each instance the end of the broken tarsus had become enlarged and hardened by use. One bird, handicapped by the loss of both tarsi, was dwarfed.

Albinism

No cases of albinism in the meadowlarks received in the laboratory have been noted. Variations in the amounts of black, yellow, and white markings have been noted, however. Specimens received from the northern coast region have been the darkest in color, those from the southeastern arid regions the lightest in color.

Abundance of the Different Sexes and of Juveniles

If the numbers of the sexes collected is any criterion of their comparative numbers, it must be conceded that males are more abundant. Fifty-eight per cent of one thousand birds received from ten different localities were males. Collectors usually obtained a larger percentage of males the first few months. This can be explained on the grounds that the male is a larger and more conspicuous bird. Then, too, it is the bird most often seen during the nesting season.

About seventy per cent of the birds collected during the summer months were juveniles. This must correspond, to some extent at least, with the comparative numbers in the field.

Incubation and Moult

If judged by the condition of the feathers on the breast, females do most of the incubation. Breeding males were noted as early as late February and as late as August.

None of the birds has been largely denuded of feathers even during the moulting period. At no time do they appear to be greatly hindered by moult.

Effect of Systematic Destruction on Numbers

A systematic destruction of birds having been carried on in connection with this investigation, there appeared an opportunity to obtain evidence as to the result which might be expected as regards a decrease in numbers. Consequently a letter was written to deputies enquiring whether there had been a perceptible decrease in the numbers of birds in the localities where collections were made. In every instance where a reply was received the deputy reported no noticeable decrease in numbers. As over two hundred western meadowlarks were collected during the year in several localities it would seem that a decrease might be in evidence. Of course, where meadowlarks are abundant such decrease would be hard to detect. However, in southern California, where meadowlarks are not so abundant, it seems strange that a decrease was not apparent.

This evidence lends support to the view that the meadowlark is a hardy, prolific bird and is capable of withstanding depletion far better than certain other birds. What the effect of placing the bird on the game list would be is not difficult to conjecture. The continued, systematic destruction which such a move would make possible would certainly have a greater effect on numbers than this comparatively slight destruction limited to not more than two years.

Death Rate

That there is a comparatively small percentage of young birds which grow to maturity is supported by the fact that during a two weeks' stay in a region where western meadowlarks were nesting abundantly, three dead nestlings were found at different times and in addition a nest of four destroyed by a hawk or weasel. The rearing of two broods, averaging three each, also supports this view. The death rate, if computed from the average number of young hatched, would be seventy-five per cent, for only two (twenty-five per cent) out of every eight survive if the population remains the same. The minimum number of meadowlarks can be expected just before the breeding season. As the minimum number remains fairly constant from year to year, it can be seen that from every pair of breeding meadowlarks, if they lived but one year, it would be possible for an average maximum of only two to reach maturity. Since the adults must live a number of years the death rate must be greater than seventy-five per cent.

The two greatest factors in the death rate are available food supply and natural enemies.

Do Protective Adaptations of Insects Protect Them From the Attacks of Birds?

In the attempt to interpret the law of natural selection emphasis has been laid on the "importance of any structure or character which enables its possessor to escape destruction." As soon as we find that one animal preys on another, we immediately seek for some character to which we can ascribe the survival of the hunted form. This has led to an overemphasis on the theory of protective adaptations.

Doubtless the interpretation we have put upon certain color characters and other characters called protective have been of value, just as our imperfect systems of classification have been of value. Yet, just as we are constantly changing and modifying original classifications, so we may expect to modify our views concerning protective adaptations.

In order to point out the view usually held, attention is called to the following quotation from Kellogg (1908): "It has been conclusively shown by observation and experiment, by several naturalists, that many insects are distasteful to birds, lizards and other enemies of the insect class. The blood, lymph or some specially secreted body fluid of these insects contains an acrid or ill-tasting substance, so that birds will not, if they can recognize the kind of insect, make any attempt to catch or eat them."

Kellogg also goes on to suggest the theory that "success" is dependent on protective adaptations. Certain animals are widespread and found in great numbers and certain others in small numbers. Those existing in great numbers are said to do so because they are protected from their enemies. Enemies are only one factor in the complex that governs the abundance or scarcity of a species, so that such a theory hardly seems justified.

The examination of so large a number of stomachs of one species of bird has furnished some interesting evidence regarding the extent to which certain insects are protected from their enemies. The evidence shows that many of the so-called protective adaptations of insects do not protect them from the attacks of enemies to the extent to which we have been led to believe.

A recent paper by W. L. McAtee (1912d) of the U. S. Biological Survey, entitled "The experimental method of testing the efficiency of warning and cryptic coloration in protecting animals from their enemies,'' clearly points out the fact that the tests of protective adaptations against natural enemies have been inconsistent, misinterpreted, and are untrustworthy guides to behavior under natural conditions.

Investigators using the experimental method have too often failed to take into account other factors instrumental in modifying the behavior of animals toward their prey. ''The rejection of various items of food by captive animals does not prove that these items are rejected by the same species under natural conditions.'' It does give some idea of the food habits, but does not furnish dependable evidence as to the food of birds in the wild.

More reliance can be placed on the evidence furnished by stomach examination, for ''there is no possibility of going back of such evidence on the choice of food.'' Its one drawback is that it does not furnish us with data as to what was not chosen.

Hence the following evidence must be considered as valuable in throwing light upon this much discussed problem. The discussion will be largely directed to such protective adaptations as stings, noxious secretions, hairs, etc., as the evidence at hand bears more directly on this phase of the subject.

More has been written on the palatability of butterflies than on any other insect. To back up the theory of mimicry it was necessary that birds be made an important enemy of butterflies. That birds are an important enemy of butterflies still remains to be proved. The fact that the records of the United States Biological Survey show that in the examination of 40,000 stomachs of birds but four cases have been found where the birds concerned had eaten butterfles would support Mr. McAtee's contention that ''butterflies are in very little demand with birds in the United States.'' On the other hand, the fact that eleven butterflies have been taken from the stomachs of western meadowlarks and that five different species of birds were found feeding on butterflies, to a greater or less extent, during an outbreak of these insects in northern California during the spring and summer of 1911 (Bryant, 1911), shows that butterflies are taken to some extent as food. The observational evidence of Mr. Tyler already quoted (p. 430) also supports the latter statement. The ten pages of evidence given by Poulton (1908) also supports the view that birds, even though they do not feed to any considerable extent on these insects, do, occasionally at least, feed upon them. Mason and Lefroy (1912), after a study of the food of the birds of India, state: "Butterflies do not form any appreciable proportion of the food of any one species of bird, though a good many birds take these insects at times."

Although identification of the butterflies found in the stomachs has often been impossible, yet it is certain that they often belonged to separate families. The difference between the pierid butterfly, *Eurymus eurytheme,* and the nymphalid butterfly, *Eugonia californica,* is great enough to show that there is little choice shown. This evidence is supported by the work of Manders (1911). He concludes: "There is no bird in Ceylon known to eat butterflies that distinctly discriminates as an adult between one species of butterfly and another." Manders also goes so far as to say: "The fact that there is no discrimination shown by adults leads one to conclude either that few or no tasting experiments were undertaken in youth, or, what is more probable, that their taste with regard to them is indifferent." One important criticism that can be made of Mander's work is that he depended entirely on observation. The criticism bears less weight, however, since the insects under observation were of sufficient size and conspicuousness to make the observational method more dependable.

Any one who has watched a bird catch a butterfly must necessarily be impressed with the skill needed. Certain agility on the part of the butterfly must aid greatly in protecting it from attack. Further study may demand a change of emphasis from protective coloration to the protection afforded by the butterfly's ability to elude its pursuer.

There appears to be evidence that birds seldom attack butterflies, thus lending support to the theory that they are protected. On the other hand, it can be seen that there is evidence that butterflies are taken regularly as food by some birds. There are doubtless many factors which enter into the problem which have not as yet been considered. Hence until further evidence is forthcoming the best conclusion would seem to be that birds occasionally eat butterflies, and that when they become extremely available the number taken is increased.

Spiny and hairy caterpillars have often been pointed out as specially well protected insects. At least fifty of the stomachs examined have contained these caterpillars. In one instance the larva of the mourning-cloak butterfly (*Euvanessa antiopa*) has been taken from a stomach. The size as well as the spiny character of this caterpillar would seem to preclude attack. Numbers of small hairy caterpillars have been taken from the stomachs. Judd (1899) states that "The hairiness of caterpillars seems to secure them from the attack of birds more effectually than do any of the protective devices so far considered." Comparing the relative abundance of these caterpillars available for the western meadowlark with those not so protected, it seems safe to say that certain of the smaller hairy caterpillars are not often passed by because of their hairiness.

Stink-bugs (Pentatomidae), in spite of their noxious secretion and disagreeable odor, form a constant article of diet for the western meadowlark. In the examination of a collection of birds from Newman, Stanislaus County, it was found that stink-bugs (*Euschistus, Podisus, Alydus, Coryzus*) had been taken every month from March to October, inclusive, and formed five and three-tenths per cent of the food for the year. Pinicate beetles (*Eleodes* sp.), having a noxious secretion, are commonly taken as food by meadowlarks.

Many stinging insects also form a constant article of diet. Chief among these are ants, bees and wasps, and cow-killers (Mutillidae). Kissing-bugs (Reduviidae) have been found in a few instances. The stomachs of two out of four birds eating reduviids were empty, indicating that the poison might have caused some discomfort. Bees and wasps are so often taken that it can hardly be said that their stinging propensities preclude attack. Probably their agility is much more important in protecting them from the attack of birds. Over two hundred ants have been taken from a single stomach. If the stings or the poison had any effect, it does not seem reasonable that a bird would feed exclusively on ants even when hard pressed for food.

The finding of scorpions in the stomachs of two meadowlarks from San Diego was a surprise for two reasons. Their size and sting would apparently protect them. In addition, their nocturnal habits and their habitat would seem to offer protection. That more were not taken is probably due to the fact that they are seldom available rather than that they are unpalatable.

The investigation has, therefore, shown that insects supposedly protected by noxious secretions, malodor, stings, etc., are taken as food by western meadowlarks. According to the old idea, the survival of these insects can be traced directly to protective adaptations. Early authors even suggested almost complete immunity from attack. In recent years this view has become modified. Judd (1899) called attention to the fact that "Biologists have not yet entirely elucidated all the details of the nature of adaptations of insects which are potently protected." The same thing can be said at the present time.

If we hold to the theory of natural selection, it is important that a certain toll be taken in order to perfect adaptation. If an insect had no enemies it would have little need of protective adaptations. Of course it may be argued that after the adaptation becomes perfected the enemies of insects learn to let them alone. Unless the variations were of the orthogenetic type, however, we could hardly expect such highly differentiated protective adaptations to exist as do exist. Kellogg's view that "success" is dependent on protective adaptations rests on this assumption. It overemphasizes the part played by protective adaptations. In the working of the principle of natural selection other principles and tendencies are working against the factor of protective adaptations, and it cannot be said that protective adaptations gain the ascendency over all other tendencies.

Unusual destruction of so-called protected insects and other arthropods can sometimes be attributed to young birds. Finn (1898) found out by experiment "that each bird has to separately acquire its experience, and well remembers what it has learned." Lloyd Morgan (1896) has also shown that birds have no instinctive knowledge of the different kinds of food, but that they examine and test everything. He also points out the fact that they have excellent memories and are able to remember sufficiently so well any unpleasant sensation that they usually avoid a recurrence.

Under such circumstances, we should naturally expect that most of the birds taking protected insects, etc., would be young and inexperienced birds. In the present investigation juvenal birds have been differentiated from adults as far as possible. Consequently evidence on this point is available. Contrary to expectation, most of the birds taking protected insects and other arthropods as food have been adult birds. Their previous experience with this kind of food is unknown. The simplest explanation is to say that birds in searching for food take that at hand and that most easily obtained.

The only evidence afforded by this investigation that birds learn to let certain insects alone is the total lack of coccinellid beetles in the food of the western meadowlark. In California at certain times of year coccinellid beetles are extremely common and certainly would form an available food for the meadowlark if they were not protected from attack. The chrysomelid beetle, *Diabrotica soror,* a beetle sometimes confused with coccinellids, is occasionally taken as food. One stomach was found completely filled with these beetles. Hence it would seem that birds can distinguish between coccinellids which appear to be noxious and certain chrysomellids which appear to be edible. They also distinguish between pentatomids with a noxious secretion and coccinellids with a similar secretion.

Movement is a very important factor connected with the problem. Allen (1912) and Roosevelt (1911) have emphasized this point of view, that any coloration is protective only so long as the animal is motionless. Allen goes so far as to say that "coloration is a minor asset in an animal's protection in comparison with its other qualities—alertness, truculence and other traits that make for its protection." This point of view has received far less emphasis than its importance justifies.

The highest expression of vision is to be found in birds. The color sense, especially, is very acute, as shown by the preponderence of cones in the retinal elements. The range and rapidity of accommodation in birds far exceeds that of man or other animals, and the accommodative and refractive apparatus is much more complex than in the other subkingdoms (Wood, 1907). Birds must, therefore, be able to distinguish readily the differently colored insects as well as to note quickly differences in size and any motion on their part. Hence the food taken must be largely the result of the reflex acts set up by the sight of food and much less as the result of studying each kind of food presented to determine its palatability. This brings us, of course, to "hunger" as one of the prime determining agents as to the kind as well as the amount of food taken.

Then, too, many insects and animals are protectively colored while at rest, but let them move and they immediately become conspicuous. Experiment has shown that most of the lower vertebrates depend largely on the movement of their prey to apprize them of its presence. A fly placed in a cage with horned lizards is unnoticed until it moves. Many a protectively colored insect must escape detection because it remains at rest. Let the same insect move and it is instantly detected.

Let us take a few examples in the food of the western meadowlark. Many of the snout-beetles (Otiorhynchidae) are inconspicuously colored and often so covered with dust as to be the exact color of the ground. Close search often fails to disclose a grasshopper on a grass-stem or weed, so well does it blend with its surroundings. The same can be said of stink-bugs. Yet all of these insects are taken in large numbers by meadowlarks. The explanation probably lies in this factor of movement. These insects, although well concealed while at rest, are not concealed when moving, but are, on the contrary, conspicuous.

An insect outside of its own environment is also easily detected by its enemies. A stink-bug, although inconspicuous on a green plant stem, becomes conspicuous on the bare ground. This again furnishes a possible reason for the large numbers of these insects found in the stomachs of western meadowlarks.

Movement and particular environment modify the value of protective or concealing coloration. There may also be still other factors which modify its value. Size and bright coloration must add to an insect's conspicuousness in both movement and change of environment. All evidence from this investigation points to the fact that although certain insects may be protectively colored, yet they are not immune from the attack of birds because of such coloration. The fact that protective coloration is of maximum utility to the insect only when it is at rest, and of minimum utility when it is moving or when it is out of its natural habitat, in a large measure explains the occurrence of these insects in the food of birds.

Cow-killers (Mutillidae) have been found in several instances. These insects are usually considered as being warningly colored. Were they as abundant as other insects the numbers taken by western meadowlarks would be insignificant. In that they are not numerous, the fact that five stomachs contained them indicates that their warning coloration did not protect them wholly from attack.

It may even be said that certain unpalatable insects are taken as food simply because they are made conspicuous by movement, thus setting up a chain of reflexes in the bird which result in their being eaten. The reflexes set up by the stimulus of the sight of food play an important part in determining the kind and amount of food taken. A bird feeding on grasshoppers would doubtless be more greatly influenced by the sight of another grasshopper than by that of a small beetle or even a cricket the same size as the grasshopper. The psychological process involved in the feeding habit has been little studied. Its importance as a factor suggests this as a fruitful source from which might come illuminating evidence on the problem.

Availability as a Factor in the Kind and Quantity of Food

Western meadowlarks collected in grain fields appear to take as food practically every kind of insect and other arthropod to be found in grain fields. Small size does not govern the kind of food, for one bird was found to have eaten aphids. Nor, on the other hand, does large size preclude attack, for pinicate beetles (*Eleodes* sp.) are eaten. Insects with stings, such as ants, bees, and wasps, insects with noxious secretions, such as stink-bugs, and even hairy caterpillars are regularly taken as food. The respective quantity of each kind taken appears to parallel their abundance and accessibility. The term *availability* denotes the totality of factors governing the food-taking of birds. In other words, in spite of the fact that birds select food to a greater extent than many other animals, they do not select kinds or quantities of food elements to the degree to which we have been led to believe from experiments on captive birds, but are governed more largely by the abundance, the ease of capture, the conspicuousness, etc., of the insect, or, in other words, its availability.

The attempt has been made heretofore to interpret the food habits of birds from the standpoint of the insect, an endeavor being made to show why certain insects were not taken as food. Looking at the same problem from the standpoint of the bird, we can say that with few exceptions the term *availability,* when defined as above, best expresses the interrelations associated with the food habits of birds. Under this term can be grouped both the objective factors concerned, such as abundance, ease of capture, conspicuousness, etc., and the psychological factors involved in the taking of food.

SOLVED AND UNSOLVED PROBLEMS IN ECONOMIC ORNITHOLOGY

In spite of the advance made in the study of the food of birds and their relation to agriculture, there are still many problems connected with economic ornithology that are still unsolved.

Great improvement in the technique of determining the food of birds has been achieved. The modern method of stomach examination combined with field observation is so far ahead of the former method of simple observation or inferential reasoning that one is led to believe that a solution of many of the problems presented is near at hand. The criteria used in determining the status of a bird have also been improved to such an extent that were it possible to obtain the prescribed kind of evidence our estimates of the value of a bird must needs be near the truth.

Our goal, "a balance of all the benefits conferred against all the injuries inflicted," is a fine ideal, but we are still unable to attain it. A great deal is still made of the fact that certain birds eat large quantities of injurious insects. Yet what are injurious insects? Insects injurious in one place may be comparatively unimportant in another place. Abundance even more than the kind of an insect appears to govern its injuriousness. Hence the direct value of the destruction of certain insects by birds is difficult to estimate.

The solution of the problem lies in a determination of the comparative abundance of insects. The censuses of birds taken by Forbes (1901) in Illinois have been of incalculable value to ornithologists and everyone regrets the lack of others of the same type. The entomologist has left this quantitative phase almost wholly untouched. Consequently the economic ornithologist, in attempting to determine the good accomplished by birds in destroying insects, has no evidence on which he can depend as to the comparative numbers of the insects upon which they feed. The difficulty of obtaining any exact idea of the numbers of a species of insect in the field is very great, but the importance and value of the information will certainly repay effort made in this direction. Economic ornithologists must necessarily await data of this kind before they will be able to point out conclusively the importance to be attached to the destruction of insects by birds.

In years past we have been wont to judge the value of a bird entirely on its food. The present tendency to regard the food habit as only one of the things to be considered in judging its value is an advance worthy of note. The esthetic value is fast coming to be appreciated by every one. It must certainly be given an important place in any adequate estimate of a bird's value.

In a broad sense food preference furnishes evidence as to the value of a bird. For instance, a bird that eats insects can be considered of more value to the agriculturist than one that subsists entirely on vegetable food. To particularize and say that a bird prefers a certain kind of insect is to tread on dangerous ground, for birds appear to be governed more largely by the abundance of an insect than by its taste. The opportunity afforded a bird for obtaining an insect appears to be a stronger factor than memory of a bad taste. Consequently the old idea of food preference must be modified to meet the modern idea of availability as a factor in the kind and quantity of food.

The exact relation which birds bear to the control of insect outbreaks remains to be worked out. There are a number of factors which tend to bring back normal conditions. Whether birds, parasitic insects, weather conditions, or other factors are of prime importance is a problem yet to be solved. The beginning has been made and significant evidence adduced. A comprehensive study of this problem would do much towards solving it.

The amount of benefit to be derived through the destruction of weed seeds is still a debated question. When such efficient measures as the weed cutter and the mowing machine can be brought into use, the amount of good accomplished in a bird's destruction of weed seeds is minimized. A weed-seed eater must be considered a less valuable bird than an insect eater where weeds are more easily controlled than insects. Better insect control measures will likewise make the value of insectivorous birds less apparent. The inherent value, nevertheless, remains unchanged. Common sense would seem to dictate the making use of natural control measures to the greatest extent possible. Herein lies the justification for emphasis on the value of birds as insect and weed-seed destroyers.

SUMMARY

Owing to the constant complaint of ranchers as to the depredations of birds and attempted legislation to take protection away from certain non-game birds, the California State Fish and Game Commission, in co-operation with the University of California, has undertaken a thorough, scientific investigation into the relations of birds to agricultural interests. The western meadowlark (*Sturnella neglecta*), owing to its depredations in sprouting grain fields, has been the first bird to be studied.

A study of the history of methods used in economic ornithology has shown that the time has come when circumstantial or partial evidence as to the food of a bird is insufficient evidence on which to determine its economic status. Nothing short of a knowledge of a bird's food for the whole year, a knowledge of its depredations, and its whole life history, allowing a balance of all of the benefits conferred against all of the injuries done, is now demanded.

The western meadowlark is distributed throughout the state, most abundantly in the great interior valleys, the grain-growing districts. It appears to be increasing in numbers in localities where cultivated crops are furnishing it better food and cover.

The investigation has included field investigation of birds at the field of action, experimentation on the amounts of food consumed and the times of digestion, and stomach examinations of the kinds and quantities of food actually consumed.

Over twenty collections from different parts of the state, made up of birds collected each month of the year in the same general locality, have been available for stomach examination. Nearly two thousand stomachs of western meadowlarks have been examined and the kind and quantity of the different elements of food tabulated.

Field investigation has shown that the western meadowlark destroys sprouting grain by boring down beside the sprout and eating the kernel. The amount of damage depends upon the abundance of the birds, the depth to which the grain is planted, the size of the field, the condition of the soil, the proximity to pasture or uncultivated land, and the time of year. The amount of damage possible is minimized by the short time (two weeks) during which damage to the young plant can result. No other crops are seriously damaged by western meadowlarks. Young meadowlarks are fed exclusively on insect food, principally cutworms and grasshoppers.

Experimentation on captive birds has shown that nestling birds consume very nearly their own weight of food every day. The time during which insects remain in the stomach is from three to four hours. The time during which grain remains in the stomach is from four to six hours. Hence the time of digestion of grain is longer than that of insects. The amount of insect food found in the stomach of a western meadowlark represents, therefore, but one-third of the daily requirement.

Stomach examination has shown that sixty-three and three-tenths per cent of the total volume of food of the western meadowlark for the year is made up of animal matter and thirty-six and seven-tenths per cent of vegetable matter. The animal matter is made up mostly of ground beetles, grasshoppers, crickets, cutworms, caterpillars, wireworms, stink-bugs, and ants, insects most of which are injurious to crops. The vegetable matter is made up of grain and seeds. Grain as food reaches a maximum in November, December, and January, insects in the spring and summer months, and weed seeds in September and October. An average stomach of a western meadowlark contains two and three-fourths cubic centimeters of food. The kind and quantity of food varies with the time of year and locality.

A study of the relation of birds to insects has shown that birds are important regulators of the numbers of insects for at least two reasons: (1) the maximum consumption of insects comes during the nesting season of birds, a time when the numbers of insects are at a maximum; (2) birds change their food habits and feed on the insect most available, thereby becoming important balancers during insect outbreaks when insects appear in abnormal numbers.

The verdict of ranchers throughout the state obtained by a circular letter has shown that there is a wide difference of opinion as to the extent of damage caused by the western meadowlark. A majority maintain that this bird does not damage crops and is, therefore, not a nuisance.

A comparison of the injuries caused by the western meadowlark with the benefits it confers shows that it does more good than harm, and so merits protection as an insectivorous non-game bird. Crops may be largely protected by drilling grain deeply or by furnishing the birds sufficient food by heavier sowing.

The examination of so large a number of birds of one species has furnished some interesting side-lights on the investigation. Evidence on such biological problems as parasitism, malformation, albinism, natural death rate, etc., has been made available.

Protective adaptations of insects do not render them immune from the attack of birds. This investigation has demonstrated the following facts bearing on the relation of birds to insects with protective adaptations:

1. Protective adaptations of arthropods such as stings, noxious secretions, hairs, etc., have been overemphasized as factors protecting the owners from the attack of birds.

2. The "availability" of an insect or arthropod, when this term is made to include the totality of factors governing the

taking of an insect by a bird, can be considered the most potent factor governing the food habits of birds.

3. Hunger or inexperience fails to account for the destruction of many of the so-called protected insects, because in many instances they form staple articles of diet.

4. The fact that coccinellid beetles almost wholly escape the attack of birds is the one thing that supports the theory that certain arthropods are practically immune from the attack of birds in spite of the fact that they are available as food. The logical explanation of the immunity lies in the possession of a noxious secretion which makes them unpalatable. Why this secretion should be more effective than that of the Pentatomidae or certain tenebrionid beetles is not known.

5. Insects protectively colored when at rest are easily detected by birds or other enemies as soon as they move. An insect outside of its natural habitat also becomes easy to detect. These factors of movement and change of habitat may explain the occurrence of certain protectively colored insects in the diet of the western meadowlark.

6. The reflexes set up by the stimulus of the sight of food, or, in other words, the psychological processes involved in the taking of food, doubtless play an important part in the kind and quantity of food taken.

A number of factors govern the kind and amount of food taken by birds. The totality of such factors (e.g., abundance, palatability, ease of capture, conspicuousness, etc.) can be expressed by the term *availability*. *Availability,* thus used, best accounts for the varying food habits of birds.

Although great progress has been made in economic ornithology, there are still a number of problems that remain unsolved, chief of which is the value to be placed on the destruction of insects and weed seeds effected by birds. Since a solution of this problem depends upon quantitative studies of the comparative abundance of different species of insects and weed seeds, economic ornithology must await such studies from the entomologist and botanist.

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EXPLANATION OF PLATES

PLATE 21

Fig. 1.—Holes bored by western meadowlarks in obtaining kernels of grain in sprouting grain field. Photograph by H. C. Bryant taken at Lathrop, San Joaquin County, California, February 28, 1912.

Fig. 2.—Sprouted grain pulled up by western meadowlarks in grain fields at Acampo and Lathrop, San Joaquin County, California. The kernels have been crushed in the bill to obtain the ''milk''.

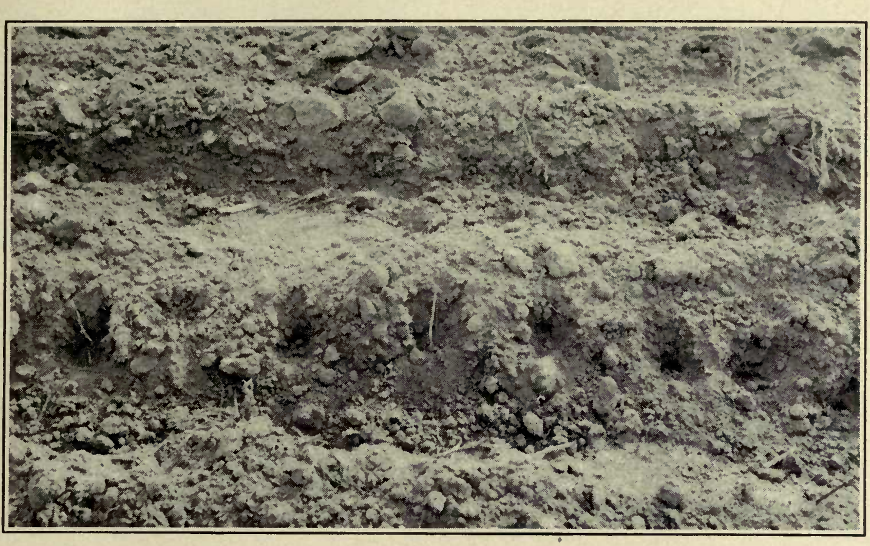

Fig. 1

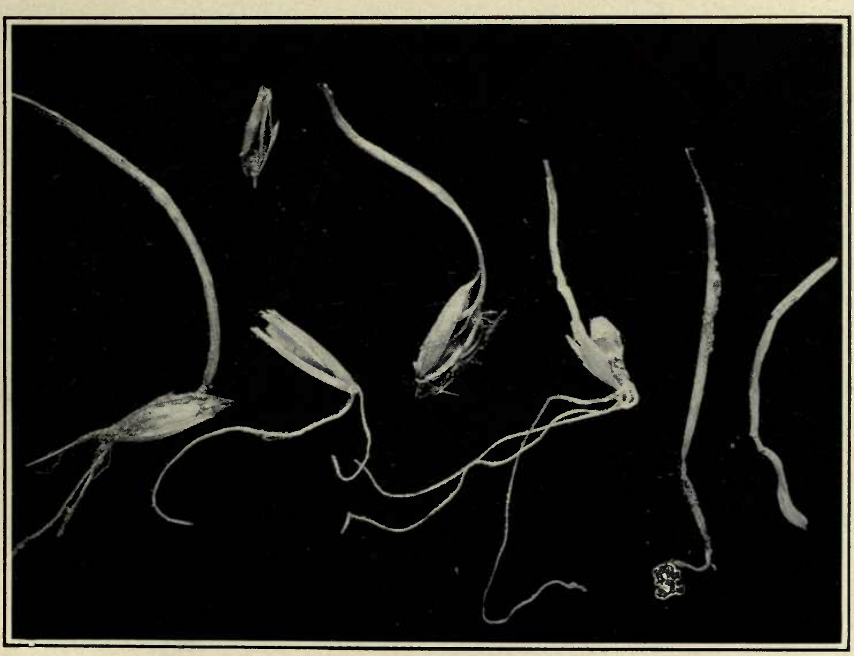

Fig. 2

PLATE 22

Fig. 3.—Photograph of the stomach contents of a western meadowlark taken in a grain field at El Toro, Orange County, California, May 5, 1911. The stomach contained 19 oat kernels, oat hulls, and parts of 2 small ground beetles.

Fig. 4.—Photograph of twelve pairs of mandibles of the common cricket (*Gryllus pennsylvanicus*) taken from the stomach of a western meadowlark collected in a grain field at El Toro, Orange County, California, April 18, 1911.

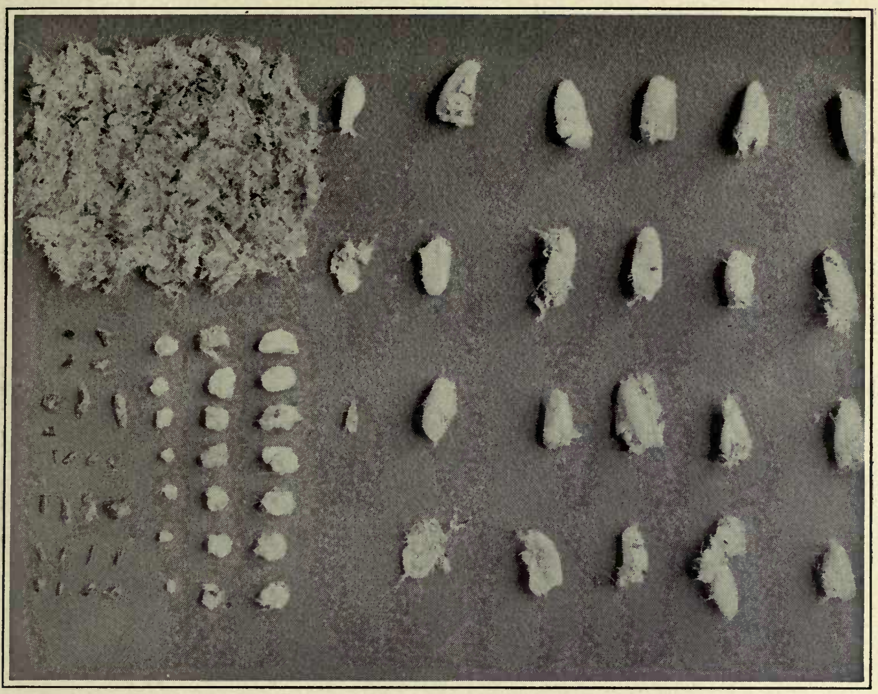

Fig. 3

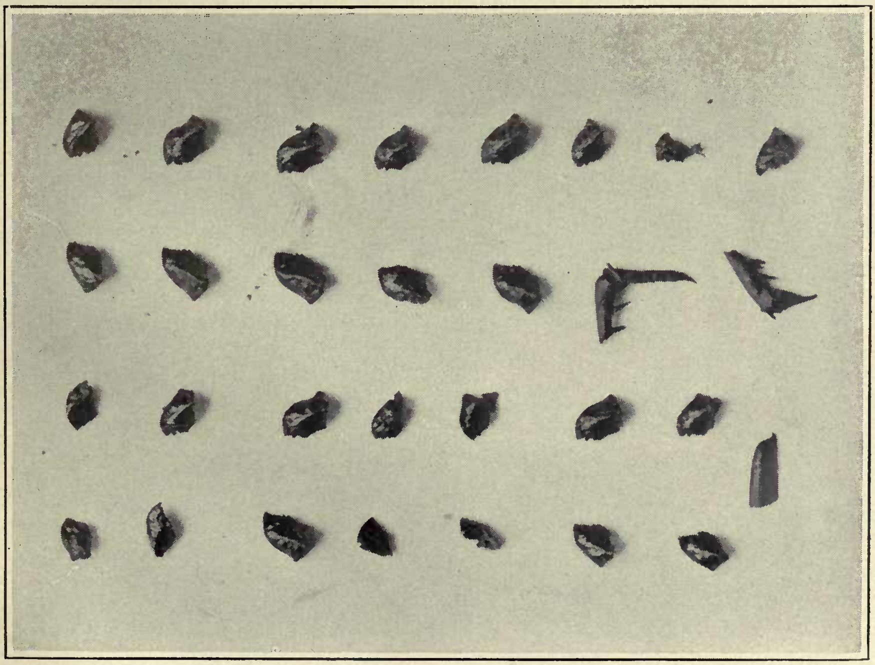

Fig. 4

PLATE 23

Fig. 5.—Photograph of the stomach contents of a western meadowlark taken at Red Bluff, Tehama County, California, February 4, 1911. Stomach contained 66 cutworms, 18 small ground beetles, 2 beetle larvae, 2 small spiders, and 18 weed seeds.

Fig. 6.—Photograph of western meadowlark killed while carrying cutworms in its bill.

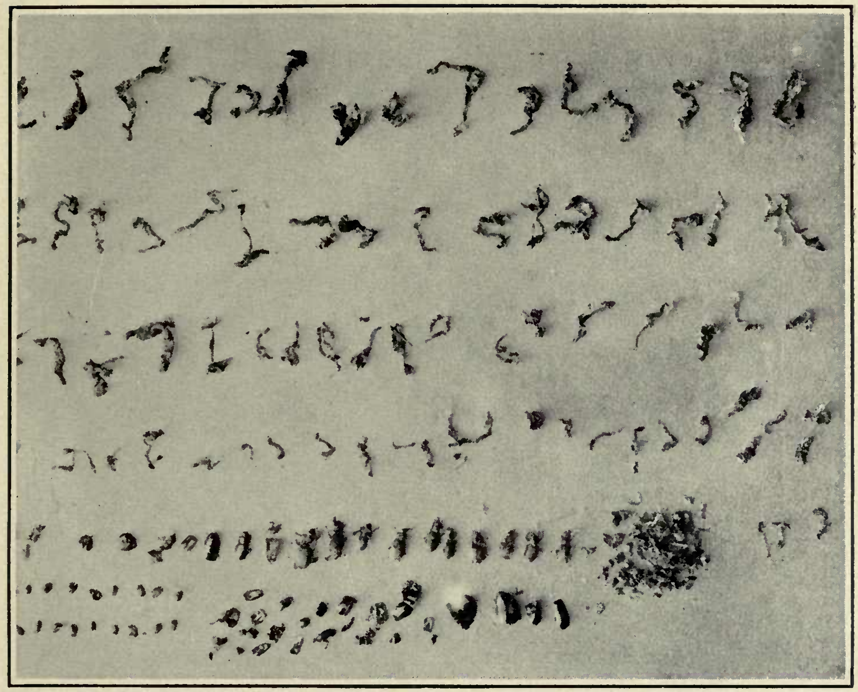

Fig. 5

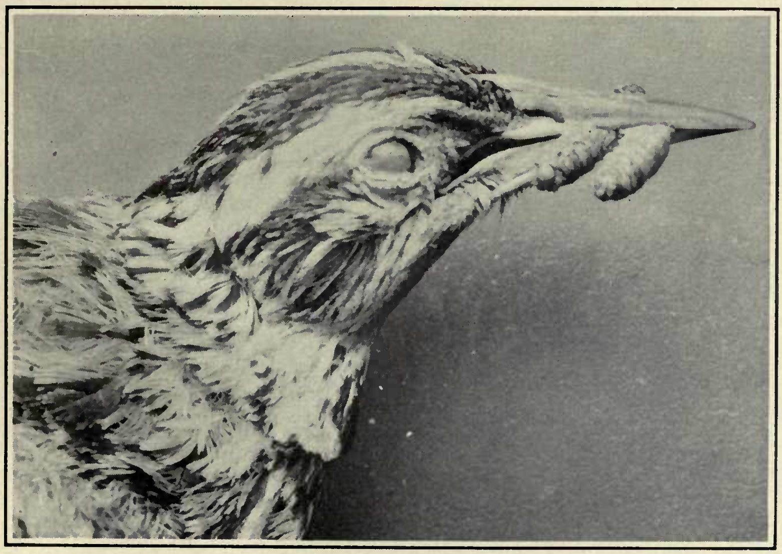

Fig. 6

PLATE 24

Fig. 7.—Photograph of stomach contents of a western meadowlark taken in a barley field at El Toro, Orange County, California, May 3, 1911. The stomach contained 2 cutworms, 44 ground beetles (*Calathus ruficollis*), 2 flies, 1 spider, and 13 fly pupae (*Syrphus* sp.).

Fig. 8.—Photograph of the stomach contents of a western meadowlark collected at Big Pine, Inyo County, California, April 19, 1911. The stomach contained 13 cutworms, 26 elaterid beetles (*Drasterius* sp.), and 10 small ground beetles (*Amara* sp.).

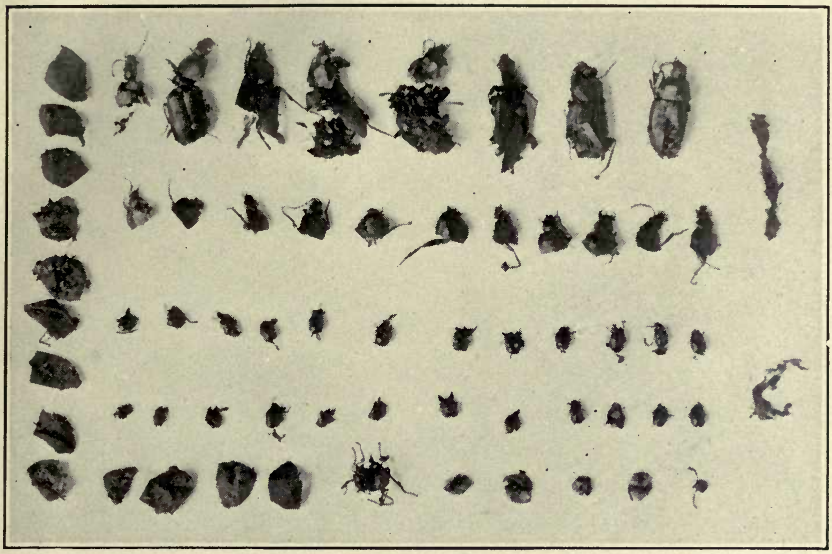

Fig. 7

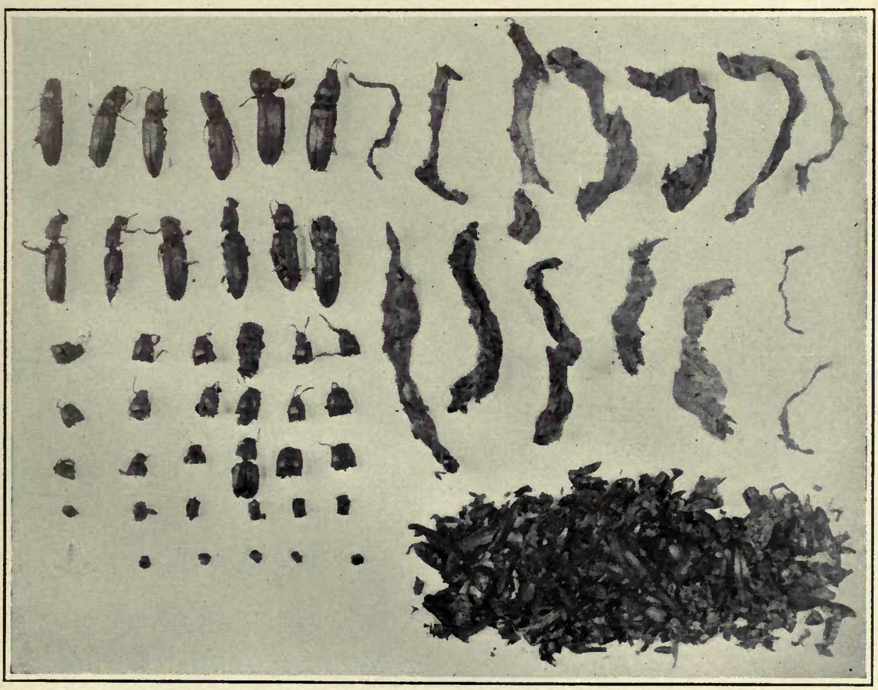

Fig. 8