A MONOGRAPH ON FOOD SELECTION IN ORTHOPTERA

BY

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[2] Contribution No. 38 from the Department of Biology, Wayne State University, Detroit 2, Michigan.

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HISTORY OF STUDY

The grasshoppers, locusts, grouse locusts, katydids, crickets, camel and cave crickets, praying mantids, walking-sticks, and cockroaches composing the insect order Orthoptera (*sens. lat.*)[4] are relatively large, readily observed, and often economically important. It is not surprising that they have been the subject of many scientific investigations. The foregoing would lead one to conclude that the group is very well understood. Such is not the case, for most research on the group has been devoted to a few rather restricted phases of the insects' biology, particularly their taxonomy and control, leaving prominent gaps in our knowledge of the group as a whole. Surprisingly, this is notably true of the insects' feeding behavior.

Riley (1878) emphasized the nearly omnivorous food-habits of *Melanoplus spretus* in outbreak populations but also showed that this species, even under these abnormal conditions, feeds differentially and, hence, is not truly omnivorous. Most entomologists, who are unfamiliar with the latter findings, regard the Orthoptera as omnivorous or, at least, highly unselective. This point-of-view has been most fully championed by Urquhart (1941). He found little, if any, differential feeding among thirteen species of grasshoppers and katydids. Ball (1936), Isely (1938, 1941, 1946), and others, to the contrary, demonstrated conclusively that differential feeding does take place in Orthoptera, particularly Acrididae.

The accumulation of feeding records has been carried on for years by entomologists. Most of the records pertaining to Orthoptera, particularly the older ones, are based on scattered, often inaccurate observations on a few species of economic interest. Furthermore, these observations were frequently made on insects under abnormal outbreak conditions. These isolated field observations are profusely distributed throughout various taxonomic, ecologic, and economic journals. More extensive studies containing feeding records, all on acridids, were published by, among others, Agrawal (1955), Ball (1936), Clark (1948), Golding

[4] The term *Orthoptera,* as here used loosely, includes insects belonging to the orders Orthoptera and Dermaptera, both of which are customarily studied by orthopterists.

(1935, 1937, 1940), Joyce (1952), and Williams (1954). Of especial merit is the work of Anderson and Wright (1952), who obtained feeding records of 36 species of rangeland grasshoppers.

Various types of differential feeding tests have been used to study food selection in Orthoptera. Savin (1927), working on *Acheta*, fed many kinds of foods to her caged crickets and used the time required for complete consumption of a given food as an index of preference for that food. Unfortunately, she studied a small, variable number of closely confined crickets. Furthermore, the time required for consumption is not necessarily an indication of preference value; the time required for consumption of coarse-textured foods is generally much greater than that for fine-textured ones, though their preference value may be identical.

Roonwal (1953) placed several different foods in a cage inhabited by many starved *Schistocerca gregaria;* after a 15-minute wait he took the number of individuals eating each plant as an index of preference for that particular food, and he compared it with the number eating *Heliotropium,* which was selected as the standard. His technique may be open to some criticism because his method of maintaining random distribution of grasshoppers may result in alteration of behavior, because starved grasshoppers are not likely to be very selective in their choice of food, and because the number of feeding individuals may be subject to counting error.

Chapman (1957) cut leaves of test grasses into small pieces, which he mixed thoroughly and placed in a heap in the center of his cages. By so doing, he hoped to overcome the tendency toward unequal presentation of foods. His locusts were exposed to these foods for one hour, after which the contents of the animals' digestive tracts were analyzed. Chapman's interesting method, though it answered his needs, may be somewhat objectionable in that cut grasses, particularly those cut into small pieces, desiccate very rapidly with consequent modification of their preference value. Furthermore, the feeding response elicited through this method of presentation of food-plants must be greatly altered from that under more natural conditions.

Other investigators have estimated food preferences by the degree of damage inflicted on several different plants during a comparatively long exposure to feeding Orthoptera. Among them are Pfadt (1949), who conducted cage experiments on *Melanoplus b. bilituratus;* Isely (1938, 1946), who performed insectary experiments on many species of Acrididae and Tettigoniidae; Clark (1948), who confined his acridines to cages enclosing parts of their natural habitats; and Duck (1944), who tested the preferences of *Schistocerca obscura* caged in nature.

Husain, Mathur, and Roonwal (1946) used cotton as a standard with which to compare other foods. They placed the same number of grasshoppers in each of two cages exposed to similar conditions. A fresh twig of the plant under trial was then placed in the experimental cage and one of the cotton plant in the control cage. The amount of leaf eaten was determined after 24 hours and, on this basis, preferences estimated.

Rau (1945) baited a number of cockroach traps, each with its own type of food. He then used the number of cockroaches caught in the traps as an index of preferences for the different foods.

Joyce (1952) estimated the preference value of various plants in terms of the number of times each was accepted per 100 presentations. As he admitted, however, data thus derived are perhaps not as refined as those from other techniques.

The analysis of crop contents has recently come into acceptance as a tool with which to study food selection of Orthoptera. Lüstner (1914) and Crumb, Eide, and Bonn (1941) examined large numbers of crops of the earwig *Forficula* to gain information on its feeding habits, and, among others, Beall (1932), Boldyrev (1928), Bennett (1904), Brindley (1918), Chapman (1957), Davidson (1943), Forbes (1905), Fulton (1915), Grassé (1922), Grinfeld (1957), Gurney (1953), Hubbell (1936), Jordan (1909), Monti (1902), Rémy (1931), Terry (1905), and Thierolf (1928), also using this method, obtained valuable data on the species they treated. Especially worthy of note is the work of Isely and Alexander (1949), who briefly described the mechanics and significance of crop analysis in the study of feeding behavior of insects, and that of Mulkern and Anderson (1959), who described a method of crop analysis which greatly facilitates identification of such materials.

Except for the study of Boldyrev (1928) and of Verdcourt (1947), who analyzed the fecula of, respectively, *Bradyporus* and *Tetrix,* there appears to be no feeding information in the literature of Orthoptera based on analysis of fecal materials.

While zoologists have long appreciated the value of using structural characteristics of animals as keys to the diagnosis of their habits, this indirect method of studying food selection has been ignored, for the most part, by entomologists. The sole feature frequently so-used by orthopterists is the armature of the legs; for example, the powerful armature of the legs of mantids and sagines has rightfully been taken as indicative of predacious habits. Further correlations between the structural characteristics of Orthoptera and their food-habits were anticipated, to a degree, by Smith (1892). Isely (1944) was the first, however, to show the close correlation between the mandibular structure of acridids and tettigoniids and their feeding habits. Gangwere (1960a, 1962, 1962a) revealed correlations between the food-habits of Orthoptera and the structure of their mouthparts and digestive tract.

In light of the above brief review of the literature it would appear that the orthopterist has at his disposal a number of excellent techniques for the study of food selection, which should have enabled him to have reached, at this time, a reasonably accurate understanding of the food-habits of the major groups and of some of the species, particularly economic ones, of the order. However, there are gaps. Most feeding studies have dealt with a few species belonging to one or two related groups of Orthoptera. There has not been a study embracing a sizable portion of an orthopteran fauna, though Isely's superb researches were directed toward that goal when they were terminated by his death. Certain rangeland faunas, which necessarily are restricted to a very limited assortment of food-plants, are, of course, partial exceptions. Neither has there been a study emphasizing availability, a factor of great importance in food selection, nor has there been an attempt at an analysis of the major factors which influence food selection, though a number of partial analyses have appeared. Finally, no studies have been made specifically pertaining to food selection in Orthoptera inhabiting a region of the eastern United States. Such a study would be valuable for comparison with Isely's work in Texas. A comparison of this nature is needed because it is here concluded that the whole question of food selection requires restudy for each different orthopteran fauna and its associated flora.

OUTLINE OF PRESENT STUDY

Field observations on feeding Orthoptera were made in southern Michigan during the 1953 through 1955 and the 1957 through 1959 seasons. During this time a total of 300 feeding records were amassed for 48 species of Orthoptera and allies. The field observations were carried out at stations in Nichol's Arboretum, a 90-acre tract belonging to the University of Michigan; at the E. S. George Reserve, a 1,268-acre wildlife preserve belonging to the Museum of Zoology, University of Michigan; and at numerous other localities in the Ann Arbor, Michigan, area. Many of these stations were visited only once or twice, but 34 were visited regularly.

Differential feeding tests were carried out repeatedly on 32 species of Michigan Orthoptera, most of them being investigated in this manner for the first time. These tests are unusual in several respects: (1) an especially large number of species belonging to the non-omnivorous groups of Michigan Orthoptera was tested; (2) an unusually large number of food-plants was used, for most species of Orthoptera were exposed to 30 or more species of plants, from which information a fairly comprehensive idea of the total range of food preference of each was obtained; (3) most Orthoptera were offered repeatedly at least 10 of the most consistently available foods, and, thus, an accurate estimate of the relative preference value of the more abundant plants of the insects' habitats was obtained.

The crop materials of 58 species and the fecal materials of 43 species of Michigan Orthoptera were analyzed. In addition, the mouthparts of 64 species were studied under the microscope, during the course of which it was posssible to classify them in terms of their structural adaptations for feeding.

METHODS

OBSERVATION OF INDIVIDUALS FEEDING IN NATURAL HABITATS

A most successful way to observe the feeding activities of Orthoptera consists of going to a selected spot and sitting there quietly for 15 to 30 minutes or so until the effect of the disturbance ceases and the insects resume movement. This technique was the one used to amass most of the feeding records presented in this study. The more conventional method of seeking feeding individuals while walking slowly through a community was also used but was not as successful. Most of the observations were made with the naked eye. Occasionally, tripod-mounted 7 × 35 Bushnell binocular field glasses were used, but it was found difficult to keep the actively moving insects in focus. The feeding individuals were collected, whenever possible, together with their food-plants, for a laboratory check of the field identification.[5] Field observations on the nocturnally active species were made with the aid of a head-lamp operated by a 6-volt battery.

UTILIZATION OF DIFFERENTIAL FEEDING TESTS

The techniques used in the differential feeding tests combine some of the features of both Isely's and Roonwal's methods, while perhaps avoiding certain faults common to experimental methods for measuring preferences. For a given food-plant they involved: (1) evaluation of the comparative degree of damage inflicted by feeding over an extended period of time; (2) counts at regular intervals of the number of individuals feeding. Care was exercised that the Orthoptera used in the experiments were not unduly crowded, starved, or disturbed during observation.

The maintenance techniques and equipment used in this study were described previously (Gangwere, 1960), but a discussion of their salient features is appropriate here. A total of 10 to 20 individuals of each species was confined in individual cylindrical screen cages 12 to 18 inches high and 9 inches in diameter. The

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[5] The methods used in the determination of all species, both orthopteran and plant, are reviewed in the Appendix.

cages were aligned on a narrow bench parallel to and 3 feet from the southern windows of a large laboratory room with windows on two sides, where the animals received direct sunlight during 5 or 6 hours of the day. The windows were left open to keep the temperature and humidity as close as possible to that prevailing outdoors.

Food-plants to be tested were clipped in the field and their stems thrust immediately into water-filled 5- or 8-ounce jars. A group of 6 to 12 plant species was assembled from the above jars to be placed in each test cage in the laboratory. In most cases, only a single plant of each forb species was used in a cage, but grasses and sedges were tied in small bunches composed of many plants. All damaged or torn leaves and flowers were carefully removed, and the total bundle of plants was placed in a water-filled tumbler. Paper was then wadded around the plant stems, which served to hold them upright in the containers and to prevent the insects from falling into the water and drowning. Finally, the tumblers were placed in the cages. Generally, no drinking water was provided because the insects proved able to get all they needed from the fresh vegetation (Gangwere, 1960b).

Fresh foods were made available to the insects during early afternoon, and, in order to count the number of individuals feeding on each food-plant, the cages were observed at hourly intervals until late night. Counts were continued during the next morning and afternoon, and the position of the plants in each cage was changed several times. During the second night, the plants were removed from the cages, and the amount of damage inflicted on each was noted and recorded. The relative preference value of each plant species was then estimated on the basis of degree of damage and number of feeding records. Sometimes the food fragments found on the floor of the cage were helpful in making this determination.

Only non-omnivorous Orthoptera were studied in the above manner, for omnivorous ones were considered so unselective as to be unproductive in tests of this type.

ANALYSIS OF CROP CONTENTS AND FECAL MATERIALS

The data from crop analysis were obtained from 4 or 5 specimens of each species studied. These individuals were collected, killed immediately in cyanide, and stored in 80% alcohol. The crops were removed by pulling the head of each animal from its body, the crop and sometimes the entire digestive tract pulling free with the head. Once exposed, the crop was slit and its contents emptied onto a microscope slide for examination in alcohol. Especially interesting preparations were made permanent with polyvinyl alcohol. Some balsam slide mounts of rhaphidophorine crop materials, prepared by T. H. Hubbell, were also studied.

Each analysis of fecal materials was based on a minimum of 50 fecula per species, of which 5 or more were examined in detail on slides. The rest were studied, dry and intact, in a more cursory fashion. To collect fecula, orthopterans were caught and placed immediately in clean, empty jars from which the pellets were gathered after 6 hours. The fecula were stored dry until analysis.

STUDY OF STRUCTURAL ADAPTATIONS OF MOUTHPARTS

The mouthparts used in this investigation were dissected from 3 or more alcohol-preserved specimens of each species studied. They were usually examined in alcohol with the aid of a binocular dissecting microscope, but permanent microscope slides were prepared of the mouthparts of smaller species. The heavily sclerotized mandibles of some species were also examined as dry preparations, in which prominences and excavations are more clearly visible than in wet ones.

DISCUSSION OF RESULTS

The results of this study are summarized in a series of tables and graphs presented in the final section of this paper. The results of the feeding observations are presented in Table I and Graph I; those of the differential feeding tests in Table II and Graph II; those of the analysis of crop contents and fecal materials in Graph III; and those of the analyses of mouthpart adaptations in Table III. More meaningful presentation of the results is given in the following discussion sections. Here, certain results of especial significance are reviewed in the light of pertinent information from the literature.

REVIEW OF TECHNIQUES USED IN STUDIES OF FOOD SELECTION

Several methods have been used in the past in the study of food selection in Orthoptera: (1) the observation of plants frequented by species of Orthoptera; (2) the analysis of food debris found in or near dwellings of Orthoptera; (3) the observation of individuals feeding in natural habitats; (4) the utilization of differential feeding tests; (5) the analysis of crop contents and fecal materials; (6) the study of structural adaptations for feeding.

The first of these methods, the *observation of plants frequented by species,* is of very limited value in the study of food selection, for, while a species is perhaps somewhat more likely to be found on a preferred than on an unpreferred food-plant, its choice of perch is often fortuitous. The unreliability of this technique is best illustrated by various carnivorous species which frequent certain plants to feed on their insect faunas but not on the plants themselves. Monophagous and oligophagous species, however, may be exceptions, for they are seldom found except on their food-plants, which sometimes comprise much of the available vegetable materials of their habitat; apparent examples of such species, as indicated by the literature, include *Aeoloplides* on *Atriplex, Sarcobatus,* and certain other chenopodiaceous plants (Wallace, 1955); *Aularches miliaris* on *Calotropis* (Chopard, 1938); *Bootettix* on *Larrea* (Ball, 1936; Rehn, 1944); *Clematodes larreae* on *Larrea* (Ball *et al,* 1942; Scudder, 1900) and probably on *Acacia* (Rehn: personal communication); *Derycoris tibialis* on *Anabasis aphylla* (Uvarov, 1928); *Graeffea coccophaga* on coconut palms (Chopard, 1938); *Insara covilleae* on *Larrea* (Rehn and Hebard, 1914; Rehn: personal communication); *Inscudderia taxodii* on cypress (Caudell, 1921; Chopard, 1938; Hebard, 1925); *I. strigata* probably on *Hypericum fasciculatum* (Hebard, 1925); *Melanoplus davisi* and *M. quercicola* on oaks

(Hebard, 1918); *Diapheromera covilleae* on *Larrea* (Rehn and Hebard, 1909); *Oecanthus pini* on *Pinus* and *Larix* (Beutenmüller, 1894; Cantrall, 1943); *Tropidolophus formosus* on *Malvastrum coccineum* (Ball, 1936); and *Schistocerca ceratiola* on *Ceratiola ericoides* (Hubbell and Walker, 1928).

No strictly monophagous or even oligophagous species are included among those investigated in this study. Consequently, the method was not used.

The second method, the *analysis of food debris found in or near dwellings* of Orthoptera, is even less generally applicable than the first because very few species have habits lending themselves to study in this manner. Furthermore, data derived in this fashion are of poor quality. The Indian crickets *Brachytrypes* (Ghosh, 1912) and *Gymnogryllus* (Singh, 1952) have been studied in the above manner. The method was not used.

The third method for the study of food selection, the *observation of individuals feeding in natural habitats,* is both difficult and time consuming to use because Orthoptera are discontinuous feeders (Gangwere, 1958) and wary, hence, difficult to approach sufficiently close for accurate observation. Nevertheless, field observation of feeding is an excellent method to obtain direct, reliable information on several aspects of the animals' feeding behavior, including their food selection, feeding periodicity, and food consumption under natural conditions. This technique may also be used as an aid in planning and interpreting experiments. Thus, a few nights' observation of *Neoconocephalus ensiger,* for example, will disclose its " seed "-feeding habits. Without such knowledge, one might perform countless differential feeding tests and yet be unsuccessful in revealing this cone-head's food-habits. Isely (1944) believed this method somewhat unreliable because he felt that field evidence of food choices by grassphoppers is difficult to obtain and easily misinterpreted. To the contrary, the present author's several years of experience with the method have convinced him of the excellence of the technique, an impression apparently shared by Anderson and Wright (1952) and others who have used it extensively.

The method contributed much of the data here presented.

The fourth method, the *utilization of differential feeding tests,* enables one to determine readily and accurately what insects eat by preference when the factor of availability is cancelled out. Beyond simply revealing food preferences, the tests offer, through the use of an acceptance-rejection ratio [6] or a similar index, a quantitative method of expressing the relative attractiveness of foods. Consequently, one may predict with some certainty the relative attractiveness of two food-plants not previously tested together. This prediction is accomplished through a comparison of their acceptance-rejection ratios or by comparing each with other plants previously tested with each. During the course of differential feeding tests, observations on food-seeking and food-taking behavior, on food consumption, and on feeding periodicity may be made.

Unfortunately, the use of the tests is not without difficulties. The results vary somewhat from test to test. This variability is expected because the rankings are based on criteria which are sometimes subjective; because the testing process is somewhat laborious, and, hence, most foods are necessarily incompletely tested; and because many factors relative to both food and feeders influence food selection. Thus, animals caged together are likely to behave abnormally in their artificial environment. This tendency is most pronounced under conditions of limited space, amount, and choice of food; for more valid results crowding must be minimized. Caged grasshoppers may also congregate toward one side of their cage by reason of their phototaxis, resulting in increased feeding on plants in that part of the cage; the alternative foods constantly must be shifted with respect to the light source to counteract this tendency. Still other behavioral factors may have to be taken into account. Not only must the foods be equally accessible, but they must be fresh and equally abundant. Because it is difficult to find plants not already mutilated by feeding, one must grow his own or resort to the use of partly damaged ones from which all injured portions have been removed. After a given exposure to the feeders, each food must be examined carefully to determine its relative damage. Such evaluations are often difficult and subjective, especially when the

[6] See foot-note 18.

plants are small, highly branched, and wilted or curled. The evaluation between totally different types of plants such as fine grasses and large, coarse-leaved forbs is especially difficult.

Differential feeding tests were conducted in this study because of the previously listed advantages they offer, which far outweigh any disadvantages.

The fifth method for the study of food selection, the *analysis of crop contents and fecal materials,* can yield both qualitative and quantitative data. The samples are easily obtained and analyzed, and they furnish information based on natural conditions. Of the two types of materials, crop contents and fecula, the former yield better data, but the latter are more readily collected and analyzed. The insects do not have to be killed to obtain fecula, and the pellets can be collected over a period of time from a single individual having access to a variety of foods. The incidence of empty crops among individuals collected at known times of the day provides information on feeding periodicity.

Data derived from these analyses are, unfortunately, much less precise and reliable than those from the observation of feeding individuals and from differential feeding tests. This may be attributed, in part, to the fact that the materials of which they are composed have been subjected to the digestive processes of the animal and, hence, are broken and much-altered. It also results, in part, from the fact that crops taken from two specimens of a highly omnivorous species may contain completely different materials, though the insects were captured within a few feet of one another.

Analyses of crop contents and fecal materials may disclose animal remains, largely fragments of insects, including their body sclerites, femora, tibiae, tarsi, setae, spines, scales (Lepidoptera), mandibles, wings, antennae, compound eyes, head capsules, cast skins, etc., most of which usually cannot be determined to order. The analyses more commonly reveal plant materials of various types, including leaf fragments of woody plants, forbs, grasses, and mosses. Floral parts such as the pappus and ray flowers of composites, perianths of other dicots, flowers and fruits of grasses, pollen of monocots and dicots, and spores of fungi and ferns may be distinguished. Hyphae, individual vascular and epidermal cells, and plant hairs and fibers often appear. Sometimes the contents are mineral in nature. Such remains are almost entirely sand grains, the presence of which is usually correlated with scavenger feeding habits.

The method was used successfully in this study.

The last method for the study of food selection, the *study of structural adaptations for feeding,* is limited in application. However, when used with discretion, it can be informative, for it is possible to make a reasonable guess about the gross nature of the food-habits of a species by examination of its mouthparts. Isely (1944) was the first orthopterist to make extensive use of the method. His researches were limited to the mandibles, which he found may vary with different kinds of foods and are, therefore, diagnostic of food-habits. The present author has extended this idea to other parts of the insect, for he has discovered that all mouthparts and even the alimentary canal possess variably developed structural adaptive features.

The present paper is concerned wholly with food selection. A detailed consideration of structural adaptations is beyond its scope but has been presented elsewhere (Isely, 1944; Gangwere, 1960a, 1962, 1962a). However, the following brief summary of mandibular adaptations taken from Gangwere (1962) is pertinent. The mandibles of carnivorous Orthoptera have hook-like, somewhat sharp dentes or " teeth," which are reminiscent of the fangs of certain predacious mammals. Seminivores or " seed "-feeders have hook-like, blunt dentes. Omnivores and forbivores have numerous, short, rather sharp dentes of fairly uniform length. Dendrophagous species, which are feeders on leaves of woody plants, have sturdy, low dentes, which may be fused into one or several continuous ridges. Graminivores or grass-feeders have dentes fused into many parallel grinding ridges, which remind one of the tooth pattern of ungulates.

The forte of this method is the ease with which it may be used, but conclusions based on this evidence alone are not reliable. The mandibles of cockroaches and of grouse locusts are, for example, of omnivorous type. The former are truly omnivorous species, while the latter, though scavengers, have a marked preference for mosses and other lower plants. The mandibles of forbivorous and of dendrophagous species of Phaneropterinae are similar, though their food-habits differ. The mandibles of *Atlanticus*, a shield-backed katydid, indicate strongly developed carnivorous habits, but the insect is as much an omnivore as a carnivore. Mandibles are subject to wear. Consequently, those of senescent individuals may be misleading. One must conclude that information from the study of structural adaptations for feeding, though of value in supplementing other data, cannot be used alone in studies on food selection.

Therefore, the method was purely a supplementary one in the present study.

REVIEW OF FEEDING IN THE GROUPS AND SPECIES OF ORTHOPTERA

It is meaningless to talk about the food-habits of Orthoptera because feeding in this order is so diversified as to defy description. A more meaningful discussion is obtained by considering the food-habits of individual families and subfamilies of the order. The following section is such a description. It stresses food selection but also includes remarks on other aspects of feeding behavior. Admittedly, the conclusions here outlined are sometimes sketchy, tentative, and subject to debate. Nevertheless, they reflect the author's impression of the food-habits of southeastern Michigan Orthoptera, which are then reviewed and expanded in light of material from the voluminous literature dealing with the subject. A considerable portion of the pertinent literature is used in the case of some groups, but in others in which the literature is more extensive only selected references are given.

The following discussion is summarized in Table IV. This table is based on a majority of the species of each group and ignores variations of food-habit which may occur in certain species.

Dermaptera: Earwigs [7]

Doru, the only earwig studied, has mandibles of omnivorous type. This nocturnally active insect was not seen feeding, but analyses of its crop contents and fecal materials showed that it may feed almost exclusively on grass pollen, though it takes some animal materials. Many individuals were placed in a cage containing ground beef and *Carex lacustris,* other sedges, and flowering plants of *Potentilla fruticosa, Solidago canadensis,* and *Spiraea alba.* The earwigs ate the meat but also spent much time visiting the stamens and pistils of *S. alba;* whether they actually ate the later is uncertain. The other plants were untouched.

The literature on feeding in Dermaptera is very extensive. In consequence, a somewhat limited number of salient references is given below.

Morse (1920) found *Prolabia* and *Euborellia* living in a slaughterhouse basement, where they were eating decomposing animal matter. Other genera have been recorded feeding on dead fish, insects, and greasy paper. Some appear to be predacious. *Labidura* feeds extensively on larvae of the cotton worm in Egypt (Clausen, 1940). Terry (1905) recorded *Chelisoches* eating living leafhoppers and other insects, and Risbec (1935) recorded additional prey of this insect. Berland (1929) described the way in which *Euborellia* penetrates rotten apples to devour larvae located in the core. *Anisolabis* and *Sphingolabis* were noted as predators of fruit flies in Hawaii and were found to be so voracious that they killed more fly larvae than they consumed (Marucci, 1955).

Strenger (1950) found that the well-known *Forficula auricularia* is not a predator but is an omnivore which prefers the stamens and pistils of flowers and also eats leaves, dead insects, and living, defenseless small animals. Other authors have emphasized its predatory propensities. Thus, it was said to eat voraciously springtails of the genus *Smynthurus* (Maclagan, 1932) and to pursue larvae of *Gracilaria syringella* on lilac (Pussard, 1926). Other records of predation by *Forficula* were listed by

[7] The Dermaptera, though an order separate from the Orthoptera, are customarily studied by orthopterists, which justifies their inclusion in this account.

De Coursey (1951), Dimmock (1884), Frohawk (1940), Hawker-Smith (1943), and McLeod and Chant (1952). Predation on aphids, as noted by Voukassovitch (1924), probably also relates to this species of earwig. Goe (1925) first claimed that *Forficula* eats only soft-bodied insects such as aphids, but later (1928) admitted that it does eat vegetable materials. Crumb, Eide, and Bonn's study (1941) revealed that it may often be a scavenger; that it consumes more vegetable than animal food, the latter of which may be taken dead or alive in the form of small insects; and that it shows no really marked preferences in its plant feedings, though lower plants, particularly mosses and lichens, are more often eaten than are higher ones. Fulton (1924) found that dead and injured earwigs of *F. auricularia* are sometimes eaten by individuals of their own species but maintained that predation is not usually carried to the point of cannibalism. Later (1927), he stated that, notwithstanding its preference for animal materials, plants form the greatest part of its diet in nature.

In summary, it is probable that most earwigs are omnivorous, but many have a tendency toward carnivorous habits, and some are highly voracious predators. The bulk of their diet in nature is, however, usually vegetable because of the comparative scarcity of suitable animal materials. *Doru*, a Michigan earwig, appears to eat pollen and some animal materials, but it, too, may be omnivorous, though having a preference for proteinaceous foods.

Blattidae: Cockroaches

Most cockroaches in this country, like *Parcoblatta*, are geophilous, nocturnal forms which live under leaves, bark, and woodland debris and seldom wander into dwellings of man. One may turn to Hebard (1917) for a discussion of the habits of several of these wild species. Many genera, however, are domestic and cosmopolitan. Examples of the latter are *Blatta, Blattella,* and *Periplaneta,* on which innumerable studies have been made, the classical one of which is Miall and Denny (1886). The domestic species live in the dwellings and other establishments of man and are especially common in restaurants, hospitals, bakeries, grocery stores, kitchens, and other places where there is organic debris, which serves as food, and considerable humidity.

Aside from the many cockroaches observed feeding on oatmeal trails (Gangwere, 1958), these insects were seen but twice feeding in nature, once on fresh rodent dung and once on a small *Crataegus* pome. Analyses of crop contents and fecal materials showed the organic debris and insect sclerites characteristic of scavengers. Preference studies were not undertaken for such obviously omnivorous animals, though a number of individuals of *Blattella* and *Parcoblatta* and some of the exotic *Byrsotria* were reared successfully in cages containing lettuce, oatmeal flakes, and bran flakes. The mouthparts of blattids are of omnivorous type.

The literature on feeding in Blattidae is very extensive. In consequence, a somewhat limited number of salient references is given below.

Tepper (1900) observed the Blattidae feeding on caterpillars and softbodied insects and considered them eminently carnivorous and cannibalistic. Green (1909) recorded predation by *Periplaneta australasiae* on a struggling winged termite. *Parcoblatta pensylvanica* was recorded by Blatchley (1920) eating dead *Tenebrio* grubs and by Rau (1940a) eating a larva of *Polistes.* Cockroaches were said by Thiagarajan (1939) to eat small earwigs of the genus *Euborellia.* The highly carnivorous *Blatta orientalis* is known to be a control for the bed bug (Pettit and McDaniel, 1918; and other authors). The cannibalistic habits of cockroaches as described by Howard and Marlatt (1902) were verified by Gould and Deay (1938) and by Rau (1940), who found that dead and injured individuals are eaten by their mates.

Though it would appear that living vegetation is less frequently taken than is dead, Morse (1920) stated that in greenhouses *Periplaneta australasiae* attacks the tender tips of the aerial roots of orchids, and Skinner (1905) described it as injurious to foliage and flowers of orchids, roses, and carnations. The nymphs of *Pycnoscelus,* another well-known greenhouse pest, were said by Caudell (1925) and by Zappe (1918) to burrow in the soil, where they eat bark from the stems of young roses, Easter lilies, and poinsettias. Fulton (1930) recorded *Parcoblatta* feeding on an apple, a record which parallels one obtained during the present study.

Cockroaches are fond of secretions and wastes of animals. Records illustrative of this point are one of an individual of *Parcoblatta uhleriana* observed during this study feeding on rodent feces, one of *Periplaneta australasiae* feeding on excrement (Blatchley, 1920), one of *Pycnoscelus surinamensis* eating chicken feces (Schwabe, 1949), and one of several cockroaches imbibing mucous from the nostrils of a sleeping human (Rau, 1940). *Cariblatta* may also feed regularly on excrement (Wolcott, 1923). Additional records of this type were listed in a very detailed report by Roth and Willis (1957).

The domestic cockroaches have food-habits of such familiarity to the entomologist that little need be said about them. It is sufficient to note that they are fond of almost any edible substance, either fresh or decayed, animal or vegetable in origin, including cardboard, paste-board, wallpaper, glue, paste, clothing, wastes of various types, water color paints, book bindings, leather, hair, and foodstuffs, particularly soft items rich in starchy materials. Among these foods are many not normally eaten by insects. In fact, as reported by Gier (1947), one individual of *Periplaneta americana* lived for 101 days on a diet of distilled water and filter-paper.

The curious *Cryptocercus,* an inhabitant of the Appalachian and Pacific Coast areas, dwells in soggy sapwood galleries within chestnut, pine, oak, and other logs, feeding on wood, the cellulose of which it cannot digest except through the agency of its symbiotic flagellates (Cleveland, 1934).

In summary, the range of foods eaten by cockroaches is astonishingly great, which justifies their reputation as omnivores *par excellence.* Nevertheless, even cockroaches manifest certain preferences. Dead plant and animal materials appear to be preferred to living ones, though both are eaten by these nocturnal insects. Animal foods are less often eaten than are plant materials probably because of their lesser availability but not because of preference. Domestic species exhibit a strong preference for amylaceous foods but eat a vast array of materials, many of which are not usually food for insects. *Cryptocercus* has food-habits like those of termites.

Mantidae: Praying Mantids

Detailed observation of mantids was impossible because of the scarcity of the introduced *Tenodera aridifolia sinensis*, the Michigan species. The few observations made during this study are based on examination of the mouthparts of preserved specimens and of the feeding process in a few caged nymphs and adults. Fortunately, the literature on these well-known predacious insects is large and fairly complete.

Most mantids are phytophilous insects color-adapted to blend with their surroundings. They remain motionless on the vegetation and await the approach of prey, but when hungry they may stealthily stalk their prey. In contrast, several xerophilous forms, *Eremiaphila* (Uvarov, 1921), *Litaneutria* (Roberts, 1937), and *Yersiniops* (Ball *et al*, 1942; Rehn and Hebard, 1909), are adapted for running on the ground and actively seeking prey, a necessity because of the severe selective conditions under which they live, and *Metallyticus* [8] is reported to run rapidly over limbs while searching under bark for cockroaches, on which it feeds exclusively.

The mouthparts of mantids, especially their fang-like mandibles, are beautifully adapted for carnivorous habits, but the well-known modifications of their fore legs for capturing prey are perhaps even more remarkable. The coxae are greatly elongated, and the femora and tibiae fold together to make a pincer armed with spines for piercing and holding captured insects. Other adaptations are their marked ability to move their head in various directions and their acute vision, which enable them to watch prey before capturing it.

Many observers, including Breland (1941), Gurney (1951), Mathur (1934), Williams and Buxton (1916), and Rau and Rau (1913), have written about the feeding behavior of mantids, and the report of Beier and Heikertinger (1952) is especially complete; thus, the behavior reported below does little more than

[8] Citation apparently erroneously attributed to Wood-Mason, 1878 (Chopard, 1938).

corroborate the results of others. Mantids pounce on their prey and capture it with their fore legs. Sometimes they commence feeding on the abdomen of the prey, and sometimes they first immobilize it by biting through the nape of its neck and then feed on its head before eating the rest of the body. The prey is eaten alive, and only the hard parts, *e.g.*, wings, legs, and jaws, are left unconsumed. Any edible parts accidentally dropped are ignored. It was reported by Ball *et al* (1942), Caudell (1902), Didlake (1926), and others that they may catch a second insect before eating the first, holding one in each spiny fore leg. This latter behavior was not observed.

Mantids refuse non-living and non-moving animals and animal materials, though Roeder (1936) and Gurney (1951) found that they accept uncooked meat thrust to them on a stick or forceps. With regard to prey, however, their food preferences are said to be negligible. Certain butterflies (Chopard, 1938), moths (Beebe and Kenedy, 1957), bugs (Barlow, 1895), and ants (Gurney, 1951) are unattractive to mantids. Breland (1941) reported that only a few kinds of insects are able to escape mantids, among them being certain highly sclerotized, hence, armored beetles. Didlake (1926) described a differential feeding correlated with growth and increase in size. She found that small insects, such as leafhoppers, fruit flies, and geometrid caterpillars, are eaten by young nymphal mantids; larger leafhoppers, larger flies, and nymphal grasshoppers by second- and third-instar nymphs; and almost any large insect, including hairy caterpillars, furry moths, stink bugs, wasps, cockroaches, grasshoppers, and mealworms, by adult mantids. A similar progression of prey was noted in *Gongylus* (Williams, 1904), *Mantis* (Rollinat, 1926), and *Tenodera* (Hadden, 1927).

The tendency of female mantids to cannibalize males mating with them has been noted in both entomological and popular literature. An early report of this behavior is that of Howard (1886). It is probably a less sensational but more realistic view that mantids eat virtually any insect close enough to be reached and weak enough to be overpowered, their own species included; thus, when copulation brings male and female together, the smaller, weaker male is often sacrificed. Rummel (1926) remained almost alone in denying the common occurrence of cannibalism during coition of mantids.

Even vertebrates may not be immune to attack by mantids. There appear in the literature many sketchy, largely unverified reports of these voracious predators attacking various small species of vertebrates. Somewhat better substantiated are records of an attack on a shrew (Teale, 1944), a mouse (Wymbs, 1939), a hummingbird (Laurent, 1933), another small bird (Burmeister, 1864), a frog (Frank, 1930; Rau and Rau, 1913), and a lizard (Mourque, 1909). Two additional records, the eating of a protesting tree frog and of a lizard, were listed by Beier (1933). A mantid was also recorded killing, though not eating, a small sunbird (Brown, 1899).

In summary, the Mantidae are the only wholly carnivorous members of the Orthoptera observed in this study. Their foods consist entirely of prey, usually insects, which they capture by means of modified fore legs and eat with mouthparts of carnivorous type. They sometimes stalk their prey but usually lie in wait for it to move close enough for capture. They have few, if any, food preferences, capturing virtually any insect which they can reach and overpower, members of their own species included.

Phasmidae: Walking-Sticks

Mouthpart studies, analyses of crop contents and fecal materials, feeding records, and differential feeding tests suggest that the slow-moving, nocturnal, phytophilous Michigan phasmid *Diapheromera femorata* is restricted to eating the leaves of certain deciduous woody plants. All feeding records were on leaves of woody plants, especially *Quercus,* though one case of nibbling on *Lespedeza,* a forb, was observed. This record must, however, represent aberrant feeding behavior. Laboratory preference tests show that *D. femorata* is highly selective, but not oligophagous, as some workers have suggested; thus, *Quercus velutina* and *Rubus* were found to be highly preferred; *Cornus stolonifera, Tilia,* and *Ulmus,* at best, moderately acceptable; and most other woody plants and all forbs and grasses completely unacceptable.

The marked preference of *D. femorata* for *Rubus* is interesting. This food-plant has not been recorded previously as a food of the phasmid, though comparatively lesser choices such as *Hamamelis, Prunus,* and *Tilia* frequently have been so listed. The failure of previous workers to observe feeding on the highly preferred *Rubus* can probably be explained by the arboreal habits of the phasmid adults, which, because of their apparent negative geotaxis, are found in the tree tops, where they feed largely on oaks. The only opportunity of adults to eat *Rubus* is on occasions when they fall from their lofty perches, as they sometimes do. The nymphs of *D. femorata* lack the negative geotaxis and occur near the ground, where the available foods are quite different. The above view accords with statements by Graham (1937) and by Williams (1907), who maintained that young nymphs of this walking-stick have feeding habits unlike those of older nymphs and adults. Older nymphs probably feed on saplings of the preferred trees and shrubs, including *Rubus*. More work is needed.

Diapheromera femorata is usually listed as a species of some economic importance, feeding on oaks and cherry, sometimes on witch hazel, as well as on other woody plants. Graham (1937), for example, observed one outbreak in which *D. femorata* first defoliated black oak and then descended to eat sweet fern and witch hazel but left untouched white oak, red maple, aspen, and conifers. Those observations accord with laboratory and field data obtained during the present study.

Phasmids other than *D. femorata,* especially adult individuals, are also phytophilous and largely restricted to feeding on leaves of certain woody plants, as illustrated by *Anisomorpha buprestoides* (Hetrick, 1949), *Aplopus mayeri* (Strohecker, 1952), *Megaphasma dentricus* (Craighead, 1950), *Podacanthus wilkinsoni* (Froggatt, 1905), and *Phyllium bioculatum* (Leigh, 1909; St. Quintin, 1907), and various other species. Such must also be the case with most European species, which, according to Chopard (1938), are encountered in a small number of shrubs belonging to the Leguminosae and Rosaceae. This dendrophagous behavior sometimes reaches the point of monophagy, as with *Graeffea coccophaga* (Chopard, 1938).

Some species choose plants other than woody ones. *Diapheromera covilleae* apparently feeds exclusively on *Larrea* (Rehn and Hebard, 1909; Rehn: personal communication). Körting (1934) listed the non-woody genera *Begonia, Euphorbia, Galinsoga,* and *Tradescantia* as possible food-plants of *Carausius morosus* but in his experiments proved this insect's preference for certain woody plants. Davis (1923) implied, but did not state, that *Diapheromera blatchleyi atlantica* feeds on goldenrods and related plants; *Pseudosermyle* was noted by Ball *et al* (1942) to feed on grasses, as were the young of *Bacillus* (Thomson, 1882); and *D. velii* and *D. persimilis* probably have non-dendrophagous food-habits because they occur in abundance in prairie and plains environments in which trees and shrubs are wholly absent (Cantrall: personal communication; Hebard, 1931).

No species of Phasmidae live as predators, though some may show a tendency toward cannibalism. Certain stick-insects are known to eat their cast skins (Severin and Severin, 1911; St. Quintin, 1907) and, under starvation, to nibble on one anothers' appendages (Beier, 1934; Roth, 1917). To the contrary, Grimpe (1921) attributed the damaged appendages of *Phyllium bioculatum* to necrosis.

In summary, most phasmids are characterized by considerable specificity of food-habit, sometimes to the point of oligophagy or monophagy. The dendrophagous habits of *D. femorata,* which shows great preference for the leaves of *Quercus velutina, Rubus,* and certain other deciduous woody plants, are perhaps typical of this family, but it would appear that there are some grass- and forb-feeders in this nocturnal group.

ACRIDIDAE, ACRIDINAE: SLANT-FACED LOCUSTS

All species of Acridinae examined in this study have mandibles of the graminivorous type. The mandibles of *Syrbula admirabilis* and of *Pseudopomala brachyptera* are typical of this condition, whereas those of *Chloealtis conspersa* show a slight tendency toward the herbivorous type. This herbivorous tendency is somewhat stronger in *Orphulella speciosa* and in *Chorthippus longicornis.*

On occasions when the author observed acridines feeding in nature, they ate grasses, except once when *Chloealtis* was seen eating dried leaves of wild strawberry (*Fragaria*). The crop contents and fecal materials of *Chorthippus, Pseudopomala,* and *Syrbula* yielded only grasses; those of *Chloealtis* and *Orphulella* also included a minor element of forbs.

The outcome of the differential feeding tests was uniform. True grasses were almost always accepted by the above five species; sedges, rushes, and the horsetail *Equisetum arvense* were often accepted; forbs and woody plants were seldom accepted and then only to the extent of being nibbled.

The last statement should be qualified. Brooks (1958) described *Psoloessa* as graminivorous but found that it also readily eats the forb *Phlox hoodii.* Phipps (1930) recorded the feeding of *Chorthippus longicornis* on blueberry leaves and, under starvation pressure, on lettuce; Richards and Waloff (1954) discovered that the related European species *C. parallelus* prefers the grass *Holcus* but occasionally eats *Trifolium* and certain other forbs; and *Chloealtis conspersa* was found, though infrequently, by Phipps and by the present author to accept forbs. The above records correlate with the fact that *Chorthippus* and *Chloealtis* are two of the three acridines mentioned above as having slight modification of their mandibles in the direction of the herbivorous adaptation. The third one, *Orphulella,* like *Chloealtis,* was found to have dicot leaf materials in its crop contents. It would appear that *Orphulella* may also belong in this occasional forb-feeding group.

The above information indicates that the species of Acridinae studied are strongly but variably graminivorous. *Pseudopomala* and *Syrbula,* both of which have strongly graminivorous-type mandibles, are exclusively grass-feeders, while *Chloealtis, Chorthippus,* and *Orphulella* are grass-feeders which occasionally or rarely vary their diet with forbs. The graminivorous, phytophilous, diurnal habits of the above Michigan species are probably typical of the subfamily, for *Acrida* (Hafez and Ibrahim, 1958), *Amphitornus* (Isely, 1938), *Chorthippus parallelus* (Richards and Waloff, 1954), *Dichromorpha* (Isely, 1946), *Eritettix* (Ball *et al,* 1942), *Mermiria* (Isely, 1938), and *Syrbula fuscovittata* (Isely, 1946), a number of slant-faces with known food-habits, are also graminivorous. While it has not been definitely established, it is probable that most acridines, including the above, starve in the absence of grasses. This latter would appear to be true of *Syrbula admirabilis*, starved individuals of which were here found to reject lettuce, one of the forbs most attractive to Orthoptera, including Acrididae, but it is not true of *Ageneotettix*, which, according to Isely (1944), turns to forbs under starvation pressure.

In contrast to the typical acridines exemplified by the above species are certain anomalous genera of the southwestern United States. Several of them, if not all, possess mandibles of forbivorous adaptation, and they are known to be forbivores which feed on one or several species of plants. The habits of these forbivorous genera have been discussed as follows: *Acrolophitus* by Isely (1937, 1938, 1944), Criddle (1933), and Anderson and Wright (1952); *Bootettix* by Isely (1944) and Rehn and Hebard (1909); *Goniatron* by Chopard (1938) and Rehn (1923); *Ligurotettix* by Ball (1936), Ball *et al* (1942), and Rehn (1923); and *Pedioscirtetes* by Ball *et al* (1942).

In summary, the Acridinae, except the anomalous genera above, constitute a group of graminivorous, diurnally active Acrididae. They select freely from among the many grasses and sedges occurring in their communities. Some of them rarely or occasionally accept forbs and, in minor amount, even leaves of woody plants, but most species probably starve rather than feed exclusively on such plants.

Acrididae, Oedipodinae: Band-Winged Locusts [9]

The mouthparts of the Oedipodinae examined in this study were of graminivorous type in *Arphia p. pseudonietana, A. sulphurea*,[10] *Dissosteira carolina*, and *Encoptolophus s. sordidus* and of herbivorous type in *Camnula pellucida, Chortophaga viridifasciata, Pardalophora apiculata, P. haldemanii, Spharagemon b. bolli*, and *S. collare*. These mouthpart data correlate positively with feeding records obtained for the species, though *Dis-*

[9] Rehn and Grant (1960) recently transferred the genera of the Oedipodinae to the Acridinae. This classification has not been adopted here because food selection in the two groups is quite different. Hence, it is convenient, if not correct, to retain the older classification.

[10] A detailed analysis of the feeding behavior of this insect is now in preparation by the author. It includes a total of 27 feeding records not here recorded.

sosteira, which also took some forb and moss material, and *Camnula,* which took only grasses, are partial exceptions.

The differential feeding tests revealed considerable variation between the food-habits of these strongly diurnal species, even those within the same genus. Notwithstanding this variation, the traditionally diverse oedipodines have, as indicated by the tests, two fairly distinct patterns of food selection, which are in harmony with their mandibular structure. Those species with mandibles of graminivorous type seldom accept forbs, and two of them, *Arphia p. pseudonietana* and *Encoptolophus s. sordidus,* are as closely restricted to grasses as are acridines, whereas those with mandibles of herbivorous type frequently accept forbs, though they have a preference for grasses. It is interesting to note that *A. p. pseudonietana* was listed by Criddle (1933) and by Isely (1944) as a mixed-feeder, an impression in direct contradiction to evidence from the present study.

Oedipodines accept grasses as readily as do acridines, though they are not restricted to them (Graph II). Additional proof is furnished by unpublished cage experiments by Gangwere on *Arphia sulphurea* and *Chortophaga viridifasciata,* in which individuals of these species survived for extended periods when restricted to forbs. Much the same can be said for *Encoptolophus s. sordidus,* which, according to Fry (1927), can produce viable eggs when restricted to lettuce.

On the basis of the available literature, it appears that most oedipodines, like the species observed in this study, are strongly diurnal in their feeding and other activities and either geophilous or phytophilous. The above-listed patterns of food selection, *viz.,* graminivory and herbivory, must also be fairly typical, for they are characteristic of a number of band-wings with known food-habits. Examples are *Arphia xanthoptera, Chortophaga australior, Trimerotropis verruculatus,* and *T. maritima interior* (Carothers, 1923), *Encoptolophus s. costalis, E. subgracilis,* and *Spharagemon collare cristatum* (Isely, 1938), and *Hippiscus ocelote* (Ball *et al,* 1942), which are graminivorous or largely graminivorous; and *Trimerotropis citrina* and *T. pistrinaria* (Isely, 1938), which are largely herbivorous.

There are, however, several interesting dietary variations in the group. Analyses of crop contents and fecal materials revealed a predominance of grass fragments, while the quantity of dicot materials was insignificant, but the analyses also produced, in certain species, a small amount of grass pollen. This content is not surprising, for pollen grains are a normal but minor component of the diet of all oedipodines and, in fact, of all grass-feeding acridids. *Spharagemon collare,* a species noted in the laboratory for its propensity to feed on grass spikelets, had a somewhat higher proportion of pollen in its crop contents than did any of the others.

Insect fragments were found in the crop contents of *Encoptolophus* and *Spharagemon collare.* This observation confirms a tendency toward carnivorous behavior in oedipodines noted by Coquillet (1886), who saw an individual of *Trimerotropis pseudofasciata* feeding in nature on the body of another grasshopper. This tendency has also been noted by the present author, who found that caged oedipodines and cyrtacanthacridines sometimes eat weak, dying, or newly dead individuals of their own and other species. While it is not certain whether the insect fragments found within the crops were a result of scavenging or of predation, the former is certainly the more likely.

The crops of several species of Michigan oedipodines also held traces of moss leaves. In fact, half of the crop contents of *Dissosteira* was composed of such material. Both *Dissosteira* and *Spharagemon b. bolli* were observed eating moss in nature. It has not been reported previously that oedipodines other than saxicolous mountain- or desert-dwellers, such as *Circotettix r. rabula* (Ball *et al,* 1942), *Heliastus benjamini* (Ball, 1936), or *Scirtetica ritensis* (Ball, 1936), feed on mosses, algae, fungi, or lichens. The author believes that mosses and lichens may well be normal components in the diet of bare-ground Orthoptera, *e.g., Arphia p. pseudonietana, Dissosteira carolina,* and *Spharagemon collare.* The above evidence lends support to this contention.

In summary, the diet of the Oedipodinae, a diurnally active group, is less uniform than that of the Acridinae. Some species are restricted or virtually restricted to grasses and sedges, while others accept forbs as readily as they do grasses, and still others, particularly certain species of the western United States, are reported to accept lower plants. As a group, however, oedipodines are largely graminivorous, accepting grasses at least as readily as do acridines, though they are not restricted to them. They may vary this diet with considerable forb material and with minor amounts of animal foods and lower plants.

Acrididae, Cyrtacanthacridinae: Spine-Breasted Locusts

The Cyrtacanthacridinae is a diurnally active, largely phytophilous group of grasshoppers. The Michigan species of this structurally and behaviorally heterogeneous group have diverse mouthparts which fit into six adaptive patterns constituting a graded series, with intermediates, ranging from graminivorous through herbivorous to forbivorous. The graminivorous adaptation apparently is not as prevalent in the Cyrtacanthacridinae as it is in the Oedipodinae and especially in the Acridinae. Only one species, *Leptysma marginicollis,* has mouthparts of this type, while seven have those of forbivorous type. Furthermore, of the eight species having the intermediate herbivorous mandibles, only one of them, *Phoetaliotes nebrascensis,* tends toward the graminivorous type, as opposed to four favoring the forbivorous.

As shown by the analyses of crop contents and fecal materials, the differential feeding tests, and especially the feeding records, forb-feeding is favored in the Cyrtacanthacridinae. In fact, this is the only subfamily of Michigan Acrididae in which the preference for forbs is greater than that for grasses. This tendency is not marked, however, for, notwithstanding some variation between species, the relative acceptability of forbs is not much greater than that of grasses; which, in turn, is not much greater than that of woody plants (Graph II).

In general, the above food-habits are correlated with mandibular form, but the relative degree of forb-feeding does not always increase proportionately to the degree of forbivorous modification of the mandibles. This latter may indicate that herbivorous and forbivorous mandibles, which are not dissimilar, serve almost equally well in forb-feeding. It may also indicate, in this case, an artificial separation of mandibular types. More investigation is needed.

There are considerable differences in food-habits among the species of Cyrtacanthacridinae. Some species, for example, *Leptysma marginicollis,* appear to be almost wholly graminivorous and probably cannot subsist in the absence of grasses, though Ball (1936) found that the latter eats cat-tail; other species, like *Melanoplus plebejus,* are graminivorous but may subsist for a time on forbs alone (Isely, 1944); others, such as *Campylacantha olivacea* and *Hesperotettix viridis* (Isely, 1938), as well as *Melanoplus keeleri luridus* (present study), are strongly forbivorous, accepting grasses but probably being unable to subsist exclusively on them; others, like *Melanoplus confusus,* are herbivorous and, hence, intermediate between the two extremes (present study), though Isely (1938) found that *M. confusus* requires forbs for survival; still others are dendrophagous, feeding on the leaves of woody plants.

Examples of the dendrophagous Cyrtacanthacridinae include *Anacridium aegyptium* (Johnston, 1924), *Appalachia arcana* Hubbell and Cantrall, 1938; Rehn and Rehn, 1936), *Aptenopedes aptera* (Davis, 1914), *Dendrotettix quercus* (Davis, 1912; Rehn and Rehn, 1938), *Melanoplus davisi* and *M. quercicola* (Hebard, 1918), and *Schistocerca damnifica* (Isely, 1944) and *S. lineata* (present study; Hubbell, 1960), all of which feed on the foliage of various broad-leaved trees and shrubs. *Melanoplus punctulatus* apparently prefers conifers but also eats leaves of deciduous trees (Cantrall, 1943). *Melanoplus splendidus* eats conifers (Ball *et al,* 1942). Some of these dendrophagous species also accept forbs. *Schistocerca lineata,* as indicated by the present investigation, accepts forbs and is quite partial to *Lespedeza.* A relative, *S. obscura,* eats various plants ranging from cotton and wheat to elm, especially the last (Duck, 1944). The Japanese species *Prumna uzume* includes several woody plants among its foods, though it selects largely from among forbs (Katô, 1940).

The polyphagy prevailing in the Cyrtacanthacridinae may account for the fact that a large proportion of the grasshoppers of economic importance in this country belongs in this subfamily. Many spine-breasts, especially when their populations are in outbreak proportions, attack almost indiscriminately grains, garden crops, trees, native grasses, forbs, dung, dead animal materials, and are even known to take cloth, rake handles, and other materials not normally food of grasshoppers and may be cannibalistic. The magnitude of their depredations has been described frequently. Two reports, that of Riley (1878) and that of Villamor (1914), are especially descriptive. Nevertheless, not all cyrtacanthacridines are polyphagous. *Aeoloplides* and *Melanoplus davisi* and *M. quercicola* are said to be oligophagous, the former on members of the Chenopodiaceae (Ball, 1936; Wallace, 1955), and the latter on oaks (Hebard, 1918). *Schistocerca ceratiola* is monophagous on *Ceratiola ericoides* (Hubbell and Walker, 1928). Other examples of monophagy and oligophagy in the Cyrtacanthacridinae have been reported.

There appears to be a carnivorous tendency in the Cyrtacanthacridinae. The author found that twenty-five per cent of the crop contents of *Melanoplus confusus* was of insect remains, and Grassé (1922), during analyses of the intestinal contents of *Orthacanthacris aegyptia,* discovered a minor amount of insect remains. The present author noted, as did Abbott (1944), several instances of cage spine-breasts feeding on weakened, injured, or dying members of their own species. Furthermore, a nymphal *Melanoplus* sp. was here observed feeding in nature on the remains of a *M. b. bilituratus* crushed by an automobile, and an individual of *M. confusus* was discovered feeding on the dried remains of a cricket of the genus *Acheta.* James (1932), who observed *M. bivittatus,* also found this genus cannibalistic in nature. Additional evidence of a carnivorous tendency is furnished by observations on spine-breasts in serious outbreak populations. As noted above, they feed on an astonishingly wide assortment of materials, including animal ones.

Cannibalism in acridids has been linked with water shortages by some authors (Uvarov, 1931), but others have attributed it largely to lack of food (Husain, Mathur, and Roonwal, 1946). It seems more likely that both lack of water and lack of food, as well as a possible innate craving for animal foods, are factors in this behavior.

The Cyrtacanthacridinae, like certain Oedipodinae examined in this study, occasionally may feed on lower plants. Two species, *Melanoplus b. bilituratus* and *Schistocerca lineata,* were observed feeding in nature on leaves of moss plants, and one species, *M. f. -r. femur-rubrum,* was found to have a small proportion of moss leaves in its crop contents. Nevertheless, in view of the paucity of such records and particularly in view of the habitat selection of most spine-breasts, which regularly are exposed to more acceptable foods, it would appear that feeding on mosses and other lower plants is not important in the subfamily, except in instances of outbreak populations.

The literature on feeding in Cyrtacanthacridinae is very extensive. In consequence, it was necessary to use in the above discussion a limited number of salient references.

In summary, the Cyrtacanthacridinae is a heterogeneous, diurnally active group with heterogeneous food-habits. Its members are largely forbivorous but select very widely from among forbs, grasses, and woody plants. Not all species manifest such latitude, however, for some are restricted to one or another of the food groups and starve in the absence of this food. This restriction seldom extends to the point of oligophagy or monophagy. Occasionally spine-breasts are somewhat carnivorous.

Tetrigidae: Grouse Locusts

The studies carried out on this group, though not intensive, were sufficient to reveal the general nature of their food-habits. They included an examination of mouthparts, observations during rearing, and analyses of crop contents and fecal materials. The mouthparts of the three species examined, *Tetrix ornata, T. subulata,* and *Tettigidea l. lateralis,* were of omnivorous type.

Food	Highly Preferred	Moderately Preferred	Taken Occasionally	Not Taken
Hypnum (a moss)	X			
Mnium (a moss)	X			
Various sprouting seedlings		X		
Muck			X	
Soggy decayed wood			X	
Bran flakes			X	
Leaf litter			X	
Lettuce				X[11]
Oat flakes				X

[11] At a later time when only lettuce was provided they ate it readily.

The above cage experiment, in which ten *Tetrix subulata* and *Tettigidea l. lateralis* were exposed to various foods, provides additional evidence of omnivorous habits.

The data obtained by analyses of crop contents and fecal materials were variable but along anticipated lines. Particles of moss leaves and organic debris, composed largely of algae, molds, and decaying vegetation, were predominate; grass seedlings composed most of the remainder of the contents; sand grains, spores, and dicot leaf materials were also present in equal, small amounts.

These observations accord generally with the few published records. Verdcourt (1947), also through analyses of fecal materials, found the diet of *Tetrix* to be composed largely of the leaves of *Hypnum* and allied mosses, the remainder being composed of stem, rhizoids, and secondary protonema of mosses, together with a very small quantity of epidermal tissues from the leaves of higher plants. He was unable to confirm the presence of algae. Hancock (1898, 1902) observed grouse locusts feeding on various substances, including black muck, decomposing soil, organic debris, algae, lichens, molds, mosses, and seedlings of grasses, sedges, and dicotyledonous plants. Cantrall (1943) on several occasions watched insects of this group as they ate heavy black muck and mosses. Somes (1914) recorded them eating tender stems of young grain and clover.

In summary, grouse locusts are apparently omnivorous-herbivorous. Most of their feeding is on decaying vegetable substances and lower plants, *e.g.*, algae, molds, lichens, and especially mosses, but they also feed on sprouts of both monocotyledonous and dicotyledonous plants. They are quite partial to black muck. They do not seem to feed on animal materials.

Gryllacrididae, Rhaphidophorinae: Camel and Cave Crickets

A few field observations were made on the feeding activities of individuals of several species of *Ceuthophilus*, a genus of completely nocturnal, geophilous camel crickets. They ate animal remains, leaf mold, and fungi. Many were also seen feeding on oatmeal trails (Gangwere, 1958). Individuals caged in the laboratory ate lettuce and flakes of bran and oats. Differential feeding tests were not attempted for such obviously omnivorous organisms. Organic debris, leaf materials of dicotyledonous plants, and spores predominated in the crop contents and fecal materials; insect remains were common components; and a few sand grains, hyphae, and grass leaves were also present. The mandibles of *Ceuthophilus* are of modified omnivorous type, an adaptation which, though different from that of cockroaches and most other orthopteran scavengers, is well-suited for such a varied diet.

Hubbell (1936) found that peanut butter is especially preferred by caged *Ceuthophilus,* but molasses, cheese, butter, jam, fruits, meat, and dead insects are also avidly eaten, while grass and other kinds of green vegetable materials are untouched, except in the absence of more acceptable food. He found insect fragments, decayed vegetation, spores, hyphae, and pollen in the crop contents. Hubbell's caged insects were not predacious, nor did they indulge in cannibalism, except when the victims were soft and helpless during molting. Turner (1915), to the contrary, said that adult females of *Ceuthophilus* possibly eat the males during copulation.

There are, in the literature, additional records pertaining to *Ceuthophilus* and related genera. Monti (1902) pointed out the important role which fecal materials of man and his domestic animals play in the diet of certain cellar-dwelling Ceuthophili; Banta (1907) found that *Ceuthophilus* feeds on organic matter and once watched an individual eat the decaying body of a mouse, as well as bait cheese; Townsend (1893) even reported *Ceuthophilus* feeding on curtains and clothes hung out to dry; Muehlberger (1938) noted that his caged *Troglophilus* ate moss but refused small insects; and two authors, Popenoe (1922) and Thomas (1939), mentioned damage inflicted on mushrooms by, respectively, *Pristoceuthophilus* and *Ceuthophilus.*

Apparently, many rhaphidophorines, like *Ceuthophilus,* are not normally predacious nor cannibalistic but are scavengers which confine their animal diet to the weak or dead. Nevertheless, there is in the subfamily a number of powerful, aggressive carnivores as prone to attack their own kind as others. Smith (1920) recorded *Udeopsylla robusta* feeding on May beetles, grasshoppers, and various other insects. Wünn (1909) found the introduced greenhouse cricket *Tachycines asynamorous* a rapacious predator, as did Boettger (1950), though the latter also discovered that this species eats vegetable materials but is unable to mature on them.

The cave-dwelling Ceuthophili, according to Bailey (1928), are more restricted to a scavenger diet than are the others. They probably eat bat dung, molds, dead insects and cave mice, and organic materials they encounter during their wanderings. Such food sources either originate there or are washed in from above. In contrast, individuals of *Macropathus,* a New Zealand cave-dweller, were shown by Richards (1954) to be omnivores which feed on leaves, grass, remains of dead insects, and sometimes living prey, some of which they must obtain in wanderings outside their cave retreats. This latter type of feeding behavior of cave-dwellers must not be uncommon.

In summary, the rhaphidophorines, which are perhaps typified by the nocturnal *Ceuthophilus,* are highly omnivorous, the variety of their diet being second to none, except that of cockroaches and perhaps field crickets. They are attracted to spores, molds, hyphae, pollen, and dead plant materials but are also fond of animal substances, largely newly dead insects and dung. A few species are aggressive predators.

Tettigonidae, Phaneropterinae: Bush and Round-Headed Katydids

Analyses of feeding records and of crop contents and fecal materials of some Michigan phaneropterines show that, in order of decreasing preference, forb leaves, forb flowers, and leaves of woody plants are accepted as food. The differential feeding tests confirm these results, revealing that forbs are consistently accepted, woody plants frequently accepted, and grasses seldom accepted by these insects of nocturnal, phytophilous habit (Graph II). Such food-habits are in harmony with the mandibles of forbivorous type[12] possessed by virtually all phaneropterines examined.

[12] Isely (1944) terms such mandibles *florivorous-forbivorous.*

The foliage of *Impatiens,* along with that of certain other succulent forbs, is greatly favored by Michigan phaneropterines. The flowers and leaves of *Solidago canadensis* and certain other composites are also taken frequently because they are both preferred and abundant in the insects' natural habitats. The leaves of various vines and shrubs, particularly *Vitis* and *Rhamnus,* proved to be more acceptable than are those of trees. The leaves of saplings of the latter are more often taken than are those of mature plants. The more succulent, tender parts of all food-plants are preferred over the coarser, older parts.

On the basis of the above, it would appear that the Michigan species of Phaneropterinae eat leaves and flowers of various forbs and leaves of woody plants and usually reject grasses and sedges. The latter checks with the little information available on these species and on *Amblycorypha p. parvipennis* (Isely, 1944) and *Arethaea grallator* (Isely, 1941), two species not here studied. One can conclude, therefore, that the Phaneropterinae is a generally phytophagous group, though, contrary to statements by Chopard (1938) and Ramme (1932), it may not be exclusively phytophagous.

Some insect sclerites were discovered in the crop contents of *Amblycorypha rotundifolia.* There are three records which perhaps bear on this surprising discovery. La Baume cited the European species *Barbitistes* as a possible predator on larvae of the moth *Liparis monacha,* though this relationship was doubted by Chopard (1938); Urquhart (1938) noted two instances of cannibalism in *Scudderia pistillata;* and *Microcentrum retinerve* was reported predacious on certain beetles (Griffith, 1882). Notwithstanding these records, one must conclude, on the basis of present information, that any carnivorous behavior, at least in Michigan species, represents somewhat aberrant feeding. The few insect fragments found in the crop of *Amblycorypha* must be considered atypical and doubtlessly the result of scavenging, not of predation.

Urquhart's work presents an anomaly. In 1938 he tested the laboratory feeding of *Scudderia pistillata* and found that this species has a marked preference for poplar and grass. In 1941 he tested individuals of *Scudderia texensis* and *S. f. furcata* and found that his caged insects accepted any of the grasses and sedges he offered them, as well as lettuce and other cultivated forbs. In contrast, the tests made during the present investigation showed, time after time, that grasses and sedges are quite unacceptable as foods, though they may be eaten lightly or nibbled, particularly during times of food shortages. Urquhart's data are so completely unrepresentative of the normal feeding behavior of phaneropterines that it is likely that his results may have been biased owing to starvation pressure. Evidence of the latter is furnished by the fact that he found *Scudderia pistillata* cannibalistic, a tendency in some starved orthopterans.

The food-habits of *Scudderia septentrionalis,* a seldom-encountered arboreal species, are largely unknown. The author was able to obtain several individuals for experimentation from the oak-hickory woods of the E. S. George Reserve and the Ann Arbor area. During two tests they ate fronds of *Pteridium* and heads of *Rudbeckia,* the former being preferred, and they nibbled several plants, particularly shrubs. These plants can scarcely be the insects' normal foods, for they grow in the shrub-forb stratum of the woods, where the animals do not live. Early mortality of the katydids helped confirm this impression. The species is probably dendrophagous, feeding on some woody plant not included in the two tests.

Microcentrum rhombifolium, according to Isely (1944), differs from most other phaneropterines in having mandibles tending toward the dendrophagous type. It eats woody plants rather than herbs, which coincides with its arboreal habits. There is, however, some evidence which indicates that this genus is not exclusively dendrophagous. Blatchley (1920) reported that members of this species can be reared on succulent forbs, such as lettuce, though such individuals are less hardy and shorter-lived than those having access to the foliage of woody plants. A relative, *M. retinerve,* has been reported predacious on certain beetles (Griffith, 1882), and another, *M. triangulatum,* is known to feed on the leaves of sweet potato and castor bean (Wolcott, 1923).

In summary, the phaneropterines, katydids of nocturnal habit, are almost completely phytophagous, probably eating, in order of decreasing preference, forb leaves, forb flowers, and leaves of woody plants, while usually rejecting grasses and sedges. A few species are, however, more dendrophagous than forbivorous and show appropriate modification of their mandibular form.

TETTIGONIIDAE, COPIPHORINAE: CONE-HEADED KATYDIDS

Only a single species of copiphorine, the nocturnal *Neoconocephalus ensiger,* was included in the present study, but it was investigated rather thoroughly. All individuals seen feeding in nature were, with two exceptions, eating grass " seeds " or grains. Hubbell (unpublished field notes) recorded a related species, *N. triops,* feeding on fruiting heads of the grass *Sorghastrum;* Davis (1889) another relative, *N. exiliscanorus,* those of *Spartina;* and Davis (1914) a related genus, *Pyrgocorypha,* those of an unnamed grass. The mouthparts of *N. ensiger* proved to be of seminivorous type, especially adapted for grass " seeds." The analyses of crop contents and fecal materials confirmed the " seed "-eating habits of the species, for the only trace of any other food consisted of a few insect remains.

In the differential feeding tests on *N. ensiger,* as in those performed by Isely (1944) on *N. robustus crepitans,* grass spikelets were consistently accepted and leaves of grasses were consistently rejected, as were leaves and flowers of forbs (Graph II). In fact, *N. ensiger* accepted the grains of virtually every true grass offered it, except those of *Elymus,* and it proved to be particularly fond of those of *Andropogon,* a plains grass which occurs in abundance in many of the animal's habitations in southeastern Michigan. It accepted commercial parakeet seed and also demonstrated a moderate preference for the fruits of several sedges common in the marsh situations in which it sometimes lives. During periods of food shortage caged individuals hesitantly accepted lettuce and grapes, presumably attracted by their high water content, but because of their mouthpart structure they were unable to feed efficiently. Starvation pressure may perhaps force them into predation. Smith (1892) observed them eating living individuals of the meadow grasshopper *Conocephalus,* and, in the present study, a small amount of the fecal materials subjected to analysis was of animal origin.

Not all copiphorines are "seed"-eaters or, at least, as restricted to this diet as is *Neoconocephalus ensiger*. Gowdey (1923) found that *N. maxillosus*, a Jamaican species, feeds on the leaves of sugar cane, and Davis (1912a) recorded the southern species *Belocephalus sabalis* as a palmetto-feeder, which gnaws the tough leaves with its powerful jaws. In contrast, a close relative, *B. subapterus*, probably has food-habits more like those of *N. ensiger* (Hubbell: unpublished field notes).

In summary, the food-habits of the Michigan species *Neoconocephalus ensiger* probably typify those of the Copiphorinae, the subfamily of nocturnally active insects to which it belongs. It is virtually restricted to grains or "seeds" of grasses, among which it selects very widely, but its diet includes some fruits of sedges. Animal foods are not a normal component of the diet but, when necessary and available, possibly may be taken at infrequent intervals. Other parts of grasses and sedges and all parts of forbs and woody plants are consistently rejected. Certain copiphorines depart from the above, eating the tough leaves of various plants.

Tettigoniidae, Conocephalinae: Meadow Grasshoppers

The mouthparts of conocephalines, insects of incompletely nocturnal habits, show an admixture of the forbivorous, seminivorous, and carnivorous adaptations. There is concomitant variability in their food selection. The feeding records obtained show that the conocephalines of southeastern Michigan prefer flowers of forbs and fruits of grasses, sedges, and rushes, but sometimes capture prey and also eat leaves of grasses, sedges, and forbs. The above correlates generally with data supplied by Isely and Alexander (1949), except for their impression that feeding on the leaves of grasses and forbs is negligible. The differential feeding tests carried out yielded data supporting the above field observations, for they showed that meadow grasshoppers have great preference for grasses and certain forbs and moderate preference for sedges, with reproductive parts of these food-plants being favored over vegetative ones. They also revealed, on the basis of Graph II, that grasses and forbs are almost equally acceptable, while both are preferred to leaves of woody plants.

Evidence from the analysis of crop contents and fecal materials presents a slightly different picture. These materials consisted primarily of dicot leaves and insect sclerites but included some flowers, fruits, and pollen of grasses and dicots. This discrepancy in proportions may be resolved if one holds that conditions in the experimental cages did not give the insects, which are characterized by great latitude in feeding behavior, sufficient opportunity to exhibit fully their broad range of preference. It may also be explained by an inadequate sampling of crops.

It is probable, on the basis of information from this study, that carnivory is well developed in the Conocephalinae, though the animals are not completely insectivorous, as Chopard (1938) thought they might be. *Conocephalus brevipennis* was observed feeding on a freshly killed, adult deerfly and on a dead, undetermined fly larva, and *C. strictus* was observed preying on an ant, a mosquito, and an undetermined insect. Other species of *Conocephalus* are known to be predacious. The Hawaiian species *C. saltator,* according to Swezey (1905), Illingworth (1929), and Clausen (1940), may be the principal agent in the natural control of mealy-bugs. Members of the genus *Orchelimum* are predacious. The author's caged *Orchelimum* ate several kinds of living animals, including nymphal *Scudderia,* reduviid bugs, coccinellid beetles, and individuals of the lygaeid bug *Oncopeltus fasciatus.* Blatchley (1920), Balduf (1943), and Knowlton and Roberts (1943) also observed predation in this genus of meadow grasshoppers. The present author's caged *Orchelimum,* as well as *Conocephalus,* were found to be cannibalistic, continually reducing their numbers by eating weaker members of their own species. The former genus, *Orchelimum,* had previously been noted as cannibalistic (Hancock, 1904; Metcalf and Colby, 1930). There is probably little choice of prey in the Conocephalinae, as in most other orthopteran predators, except that based on size and inability of the prey to escape or to defend itself.

Conocephalines exhibit distinct preferences, even though they select widely from among many different kinds of foods. They prefer living to dead materials, whether plant or animal. Animal foods are probably preferred over plant foods, but they are less often taken because of their lesser availability. Among food-plants, grasses, sedges, and forbs are taken, in general order of decreasing preference, but species differ markedly in the relative preference they show for these foods. Reproductive parts of plants are preferred over vegetative ones.

In summary, the Conocephalinae, a group of incompletely nocturnal insects, feed on a very wide range of foods. They are predacious, but a large part of their diet in nature is necessarily composed of the flowers and leaves of certain forbs and the fruits of many grasses and sedges.

TETTIGONIIDAE, DECTICINAE: SHIELD-BACKED KATYDIDS

Observations were made on the food-habits of but one species of decticine, the incompletely nocturnal *Atlanticus testaceus,*[13] during this study. Its mandibles are of carnivorous type. Insect fragments predominated in the crop contents and fecula, but a small amount of dicot leaf material and organic debris was also present. Caged individuals ate pieces of meat, fruits of blueberries (*Vaccinium*) and strawberries (*Fragaria*), lettuce, flakes of oats and bran, a variety of species of forbs, including both leaves and flowers, and leaves of grasses and woody plants. They showed greatest preference for the meat and fruit. They were also predacious on various flies, beetles, bugs, and grasshoppers. These observations accord with published accounts. Cantrall (1943) observed *Atlanticus* eating disabled individuals of *Melanoplus b. bilituratus,* and Davis (1893) found it fond of various fruits ranging from raspberries to watermelon. It is evident that *Atlanticus* should be classed as omnivorous-carnivorous, having a strong preference for animal foods obtained by predation and scavenging but often eating vegetable materials, especially fruits.

Many members of the Decticinae possess food-habits similar to those of *Atlanticus,* while some have a wider and some a more restricted range of diet. The Mormon cricket (*Anabrus*) and the coulee cricket (*Peranabrus*), outbreaks of which may do great damage in the western United States, have even greater latitude in their food selection than does *Atlanticus.* According to Corkins (1923), Gillette and Johnson (1905), La Rivers (1944), and

[13] A detailed analysis of the feeding behavior of this insect is now in preparation by the author. It includes a total of 39 feeding records not here listed.

Melander and Yothers (1917), these shield-backs feed indiscriminately on grains, native grasses and forbs, garden vegetables, dung, urine, and dead and dying animals of all kinds, often members of their own species. In fact, Swain (1940) discovered 403 species of plants on which *Anabrus* feeds, to say nothing of its carnivorous and cannibalistic propensities. However, *Peranabrus* was said by Snodgrass (1905) to be largely a scavenger on the dead and dying when in stationary bands and phytophagous when in migrating bands.

In contrast to the above highly omnivorous shield-backs, *Pediodectes* is almost restricted to an animal diet obtained largely by predation, though it feeds to a limited extent on the flowers and fruits of certain forbs (Isely, 1941). *Decticus,* which is known to feed voraciously on acridids, is even more restricted to an animal diet (Teyrovský, 1951). The species of *Aglaothorax, Idiostatus,* and certain other western genera were said to feed principally on leaves of dicotyledonous plants (Tinkham, 1944), though Rehn and Hebard (1920) found *A. segnis* only on *Juniperus.* Another species, *Acrodectes philopagus,* feeds on lichens (Rehn and Hebard, 1920; Tinkham, 1944), the only vegetable materials available in its barren, rocky alpine habitation.

In summary, it is probable that many species of the Decticinae, like *Atlanticus testaceus,* are omnivorous-carnivorous, but this behavior may be by necessity rather than by preference. When their preferred animal foods, which are taken by predation and by scavenging, are not available, they eat fruits, flowers, and foliage of living plants. Some species depart from the above diet, being primarily predators, while others are largely vegetarians.

Gryllidae, Gryllinae and Nemobiinae: Field and Ground Crickets

The Gryllinae and Nemobiinae, insects of incompletely nocturnal, largely geophilous habits, are sufficiently close in morphology and in feeding behavior to be discussed together, and in the past there has been some question whether they should be combined into a single subfamily. The mouthparts of the gryllines and nemobiines examined in this study proved to be of omnivorous type, but they tend toward the forbivorous. Analyses of the insects' crop contents and fecal materials showed an extremely varied diet, the components of which were: in greatest amount, organic debris and dicot leaf materials; in lesser amount, insect remains; and, in least amount, spores, pollen, fragments of grass leaves, and sand grains. Caged individuals of *Acheta pennsylvanicus* ate, in approximate order of decreasing preference, meat, oat flakes, lettuce, and bran flakes, all of which were readily accepted. *A. domesticus* was also maintained in the laboratory, with approximately the same results. Several feeding records were obtained in nature: *Acheta pennsylvanicus* was twice seen feeding on animal remains and once each on mucous, oak flowers, and grass spikelets; and *Nemobius* was found nibbling on inflorescences of *Daucus*. Numerous individuals of *Acheta* and *Nemobius* were seen feeding on oatmeal trails (Gangwere, 1958).

The literature on feeding in Gryllinae is very extensive. In consequence, a somewhat limited number of salient references is given below.

Savin (1927) discovered that *Acheta* accepts as food any of forty-two different kinds of materials, including fats, proteins, and minerals, as well as rubber, which proved to be an especial delicacy. Severin (1926) and others inferred, however, that it is normally somewhat more restricted, being a vegetarian which selects widely from among many different plants in its habitat, preferring flowers and fruits but eating all parts of its food-plants, both living and dead. Obviously a scavenger, it is reported to relish fresh cow manure (Wolcott, 1923). It has been reported taking animal foods, particularly insects, by scavenging. Among the latter records are ones of feeding on dead birds, mammals, reptiles, and amphibians (Severin, 1926); dead insects, especially grasshoppers (Putnam, 1947); and crickets, moths, cockroaches, and tiger beetles (Folsom, 1931; Folsom and Woke, 1939). *Acheta* is also known to prey on eggs of *Mantis religiosa* (James, 1945) and on those of grasshoppers (Criddle, 1925). Only McColloch (1915), who watched a cricket devour eleven termites emerging from their holes, has noted aggressive predation in this genus.

The economic literature is replete with accounts of damage by *Acheta* to various crops, including grains, corn, tomato, cotton, clover, sweet potato, pea, bean, tobacco, mushrooms, strawberry, cranberry, canteloupe, watermelon, squash, pumpkin, beet, and carrot. The insect generally eats the foliage of these plants, but sometimes it eats the flowers, fruits, stems, and even roots. Similar records are listed for the less-destructive genera *Anurogryllus* (Caudell, 1904), *Gryllodes* (Caudell, 1908), and *Nemobius* (Blatchley, 1920).

It would appear, on the basis of the present study, that *Nemobius* has food-habits similar to those of *Acheta*. Information supplied by Richards (1952) supports this conclusion. He studied *Nemobius sylvestris,* a European species, in the laboratory and also obtained feeding records in nature, once on pomes of apple, and several times on various fungi. He concluded that the cricket's diet is largely composed of fungi, including molds and mildew, but that dead insects, fallen acorns, leaf galls, and honeysuckle foliage are supplementary items of food. He further asserted that animals are eaten by *N. sylvestris* only when dead or very weak. A relative, *N. allardi,* is also known to scavenge animal materials; Cantrall (1943) discovered the latter eating a dead *Peromyscus*. Caged individuals of both *Nemobius* and *Acheta* were frequently observed in the present study feeding on injured and weakened individuals of their own and other species, which is an act intermediate between predation and scavenging. *Nemobius,* like *Acheta,* eats eggs of *Mantis religiosa* (James, 1945).

While there are few detectable differences in the food-habits of the above-described native species of *Nemobius* and *Acheta,* a member of the latter genus, *A. domesticus,* differs notably. This species, which was reared in the present investigation, is a house-dweller having food-habits similar to those of domestic cockroaches. It eats dead insects, cloth, paper, bread, sugar, bran and oat flakes, fruits, meat, and other foodstuffs.

In summary, ground and field crickets are incompletely nocturnal and omnivorous or perhaps omnivorous-herbivorous, eating many different kinds of foods but showing great preference for plant materials, especially flowers and fruits. They are not usually predacious or, at least, aggressively so, but they feed avidly on the dead bodies of all animals, which, in their habitations, are usually insects. They probably are not cannibalistic in nature, except on weakened or newly dead individuals of their species. One cricket, *Acheta domesticus,* has food-habits like those of domestic cockroaches.

Gryllidae, Oecanthinae: White Tree Crickets

The mouthparts of the Oecanthinae, like those of the other crickets here studied, are of modified omnivorous type, though their diet is somewhat more specialized. In the field these nocturnally active animals were often seen eating forb flowers and sometimes forb leaves, prey, and leaves of woody plants. In the differential feeding tests the tree crickets selected only forb flowers, but when lettuce was provided alone it was greedily eaten, for in succulence and texture it is apparently very similar to floral materials. Animal food was not provided but doubtlessly would have been taken. Insect remains and organic debris predominated in the crop contents and fecula; and spores, dicot pollen, and dicot leaves were common. These observations accord well with those of Fulton (1926), who found that oecanthines eat fruits, leaves, floral parts, and fungus fruiting bodies, as well as small, easily captured insects.

While the total amount of plant materials eaten by oecanthines probably surpasses that of animal materials, the latter may be preferred when available, or so one would suppose on the basis of their fiercely aggressive manner during predation. They were observed rapaciously eating aphids during the present investigation. This type of behavior was noted previously by Houghton (1904, 1909), by Knowlton (1947), and by other entomologists. According to Parrott and Fulton (1914), the white tree crickets feed on scale insects, small bugs, leafhoppers, various small wasps, and other soft-bodied insects. Murtfeldt (1889) reported that her crickets perished without animal foods, but whether their presence is imperative is uncertain. Fulton (1915) found that cannibalism is not infrequent, for nymphs which are unable to free themselves from their egg shells are eaten by their fellows. Some students of the group have concluded that adults may be more phytophagous than are immatures and, hence, that predation diminishes with increased maturity (Comstock, 1881; Parrott and Fulton, 1914; Riley, 1889), but there is no recent information on this point.

In summary, the Oecanthinae, insects of nocturnal habit, feed on a limited assortment of foods compared with other kinds of Michigan crickets, restricting themselves principally to flowers and prey but also taking certain forb leaves and fruits. Aphids are among the most common prey eaten by these delicate but voracious insects, but they also eat many other small, soft-bodied insects.

GRYLLOTALPIDAE: MOLE CRICKETS

Only one species of mole cricket, *Gryllotalpa hexadactyla*, was studied. The crop contents of several of these burrowing insects were largely composed of insect remains and organic debris, but they also included particles of dicot leaves. The mouthparts, as one would suspect from the above analyses, were of modified omnivorous type. One individual was caged. For a short time before dying, it ate roots of grasses.

The Gryllotalpidae are fossorial forms *par excellence*. As has often been noted in the literature, they use their modified fore legs much as do moles to burrow through loose soil. Authors differ about the relative amount of plant and animal foods consumed by these omnivores. Weiss and Dickerson (1918) discussed this point. Mole crickets are said to eat the tender roots of plants, either living or dead, and also fruits and foliage on the surface of the ground (More, 1924; Chittenden, 1903). Though Barrett (1902) and Van Zwaluwenburg (1918) reported that a relative of *Gryllotalpa*, *viz.*, *Scapteriscus*, feeds almost wholly on living plants, other authors have emphasized the carnivorous habits of mole crickets. Thus, Craighead (1950) found that they feed on insects and earthworms, as well as on roots, and Chopard (1938) described them as voracious predators on worms, snails, and crickets. Baumgartner (1911) discussed their cannibalistic habits and Thomas (1928) their strong attraction for fresh horse droppings.

In summary, the Gryllotalpidae are fossorial insects of omnivorous food-habits, eating, among other things, roots of plants, either living or dead, and bodies of animals, including insects and earthworms.

REVIEW OF FOODS TAKEN BY ORTHOPTERA

In light of the foregoing account of feeding in the groups and species of Orthoptera it is apparent that the food-habits of these insects are extremely varied. So diverse are they that it is perhaps necessary to reconsider and clarify them, this time on the basis of food categories. This need is answered in the following section. Citation of feeding records will not be included below, except where records have not been given in the preceding section.

The diet of Orthoptera consists of numerous kinds of food substances, including both plant and animal materials. The former are taken in the form of (1) *plant products and secretions,* (2) *dead plant materials,* and (3) *living plants,* both wild and cultivated.

Numbered among the *plant products and secretions* in the diets of Orthoptera are foodstuffs, *e.g.*, flakes of bran and oats and bread, which are eaten by *Acheta domesticus* and domestic cockroaches; cloth, eaten by *A. domesticus* (Kemper, 1937), *A. pennsylvanicus,* certain Acrididae (field notes of author), *Ceuthophilus,* domestic cockroaches, and *Gryllodes* (Davis, 1914); rubber, eaten by *A. pennsylvanicus;* paper and cardboard, eaten by *A. domesticus,* domestic cockroaches, and the stick-insect *Carausius* (Sargent, 1937); paste, eaten by *A. domesticus* and domestic cockroaches; and extrafloral secretions, eaten by *Ceuthophilus, Conocephalus* (Nishida, 1958), and others.

The *dead plant materials* eaten by Orthoptera include both newly dead and well-decomposed substances. While the consumption of both are examples of saprophagy, the former is close to phytophagy. Such materials compose considerable parts of the diet of the Blattidae, Gryllinae, Gryllotalpidae, Nemobiinae, Rhaphidophorinae, and Tetrigidae.

Of considerable interest is the fact that many Orthoptera accept dead, dry vegetable materials of a type they would not ordinarily accept in the living, green condition. Examples are *Chloealtis,* a graminivore, eating dried, brown leaves of *Fragaria* (wild strawberry); *Scudderia c. curvicauda,* a forbivore, those of the sedge *Carex tribuloides;* and *Arphia sulphurea,* a graminivore, those of *Quercus velutina* (oak).[14] Certain graminivorous acridines (Anderson and Wright, 1952) and *Melanoplus b. bilituratus* (Scharff, 1954) ate dead, dried plant materials found on the ground. These records suggest that much of the specificity which grasshoppers and their allies exhibit in selection of living food-plants may be lost on death and desiccation of the plants.

The *living plants* eaten by Orthoptera include a wide assortment of both juvenile and mature forbs, grasses, sedges, rushes, horsetails, ferns, mosses, algae, fungi, and lichens, as well as woody plants, including both evergreen and deciduous trees, vines, and shrubs.

Belocephalus sabalis, certain Cyrtacanthacridinae, *Microcentrum rhombifolium* and certain other Phaneropterinae, and most Phasmidae, which select as food the leaves of deciduous trees or shrubs, both sapling and mature, are among the Orthoptera which eat woody plants. *Morsea californica* (Ball, 1936), *Melanoplus punctulatus,* and *M. splendidus* eat the foliage of coniferous trees. The first of these, *Morsea,* also has been recorded perched on *Arctostaphylos* (Rehn and Hebard, 1909a). While the stems and roots of woody plants are not usually attacked by grasshoppers and allies, the decaying wood of chestnut, fir, and pine offers both shelter and sustenance to the gallery-making cockroach *Cryptocercus,* the symbiotic intestinal fauna of which enables it to digest its cellulose-laden food.

All parts of forbs or broad-leaved herbs, especially their leaves, are accepted by one or another of the Orthoptera. In fact, most members of every Michigan group except the Acridinae, Copiphorinae, Mantidae, and Phasmidae take, in one form or another, such materials. The Blattidae, Conocephalinae, Cyrtacanthacridinae, Decticinae, Dermaptera, Gryllinae, Nemobiinae, Oecanthinae, Oedipodinae, Phaneropterinae, and Tetrigidae regularly

[14] This *Arphia* record, one not contained in the present report, will appear in a paper now in preparation.

or occasionally eat forb leaves and, usually to a lesser extent, their stems and reproductive parts. In addition, the Blattidae, Gryllinae, and especially the Gryllotalpidae frequently eat forb roots and stems, and the Blattidae, Decticinae, Dermaptera, and Oecanthinae reproductive parts of forbs, including their flowers and fruits.

Grasses, sedges, and rushes are here grouped as a single food-type because of their essential similarity in form, texture, and silica content and because of their similarity in terms of attractiveness to Orthoptera. The leaves and, to a lesser extent, the stems and reproductive parts of these monocots are eaten regularly by the Acridinae, Cyrtacanthacridinae, and Oedipodinae, the first of these three groups largely being restricted to them. The Tetrigidae sometimes eat sprouts of grasses. Furthermore, certain Dermaptera feed on grass pollen, and the Conocephalinae and Copiphorinae eat the flowers and fruits of these plants. The Gryllotalpidae eat their roots.

Other types of living plants, including horsetails and scouring rushes, ferns, mosses, algae, fungi, and lichens, are much less commonly accepted as food by Orthoptera but are, notwithstanding, sometimes taken in quantity by certain species. Horsetails and scouring rushes of the genus *Equisetum* are quite acceptable as food to numerous caged Oedipodinae and Cyrtacanthacridinae, and they must be a commonly selected food of these insects in nature. Ferns, however, are seldom food for Orthoptera, though the phaneropterine *Scudderia septentrionalis* may sometimes eat *Pteridium*, and certain species of *Ceuthophilus* proved to have fern spores among their crop contents. The cricket *Hapithus* is recorded as having fed especially on ferns in greenhouses (Morse, 1916, 1920).

Various scavengers, including certain Dermaptera and many Blattidae, Gryllinae, Gryllotalpidae, Nemobiinae, and Rhaphidophorinae are either suspected or known to select as food the lower plants. Mosses are a particular favorite of the Tetrigidae, which are also known to eat algae, fungi, and lichens. Grasshoppers may feed on lower plants, for certain Cyrtacanthacridinae and bare-ground Oedipodinae were here found to have such habits. The Oecanthinae, which normally eat flowers and leaves of higher plants and bodies of small insects, are known to eat fruiting bodies of fungi. The decticine *Acrodectes* has been reported a lichen-feeder, and indeed there is no other food available in its alpine habitat. The earwig *Forficula* is known to eat mosses, lichens, algae, fungi, and probably ferns.

In general, plant materials are more frequently taken by Orthoptera than are animal ones, but this does not mean that the latter diet is uncommon. Carnivorous food-habits are well developed in many groups, sometimes to the complete exclusion of phytophagy. Animal foods may be selected in the form of (1) *animal products, wastes, or secretions;* (2) *dead animal materials;* and (3) *living animals.*

The *animal products, wastes, or secretions* eaten by Orthoptera include dung and excrement, which are taken by many Acrididae, Blattidae, Decticinae, Gryllinae, Gryllotalpidae, Nemobiinae, Rhaphidophorinae; mucous, taken by certain Blattidae and Gryllidae; perspiration, taken by Blattidae and Gryllidae, as well as by certain Conocephalinae,[15] Cyrtacanthacridinae,[15] and Oedipodinae;[15] toenails and hair, eaten by cockroaches (Gates, 1912; Lugger, 1898); epidermal secretions, eaten by *Myrmecophila* (Wheeler, 1900; Beall, 1929); glue and leather, eaten by *Acheta domesticus* and domestic cockroaches; and, finally, household meat or meat products, eaten by *A. domesticus* and domestic cockroaches.

There are two distinct classes of food which may be considered under the heading of *dead animal materials.* These classes include old, partly decomposed materials and fresh, newly dead ones. The former are eaten by a host of Orthoptera, including members of the Blattidae, Conocephalinae, Decticinae, Dermaptera, Gryllinae, Gryllotalpidae, Nemobiinae, and Rhaphidophorinae. The latter, newly dead materials, which are really somewhat intermediate between dead and living substances, are taken by all of the above insects, as well as by the Cyrtacanthacridinae and Oedipodinae and perhaps rarely by certain Phaneropterinae.

The last class of animal food, *living animals,* composes the diet of a surprisingly large number of groups of Orthoptera.

[15] Field notes of author.

Some species eat normal, active prey which they catch by overtaking it, by stalking it, or by lying in wait for it to move close enough for capture. The more powerful, faster of them eat virtually anything which they can catch and overpower, including some large, heavily sclerotized insects. Among them are *Clonia* (Akerman, 1932), *Saga* (Bérenquier, 1905; Burr, Campbell, and Uvarov, 1923; Chopard, 1946), and *Rehnia*,[16] which are exotic katydids of the Saginae and Listroscelinae; certain Decticinae (*Decticus, Pediodectes*) and Rhaphidophorinae (*Tachycines, Udeopsylla*); and most of the Mantidae, which are so voracious and powerful that few insects are able to escape them, and which overcome even small vertebrates.

Other predacious but less powerful Orthoptera usually prey on smaller, weaker, more soft-bodied insects, ranging from aphids to nymphal grasshoppers but sometimes including larger, clumsy, slow-moving katydids, caterpillars, and other insects. Among these latter predators are the Conocephalinae; the Oecanthinae, which are fierce predators on aphids; the Gryllotalpidae, which are said to be predacious on insects and earthworms; and certain Blattidae (*Blatta orientalis,* said to be a bedbug predator); Dermaptera; and Gryllinae (*Acheta* eating termites).

An even larger number of Orthoptera take living animal materials in the form of teneral, injured, weakened, or dying prey. If the prey is close to death and not moving actively, it may be passed up by mantids and other more powerful predators, but most of the above predacious Orthoptera willingly accept weakened prey. Some additional groups not usually considered predacious also may accept such prey; the Blattidae, Cyrtacanthacridinae, Gryllinae, Oedipodinae, Rhaphidophorinae, and perhaps the Nemobiinae are numbered here.

In most cases the prey consists of species different from that of the predator, but virtually all of the above groups of predacious Orthoptera will occasionally prove cannibalistic, and the Mantidae, certain Decticinae, Listroscelinae, and Rhaphidophorinae, and, to a lesser extent, certain Conocephalinae practice cannibalism regularly.

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16 Laboratory notes of author.

REVIEW OF FACTORS WHICH INFLUENCE FOOD SELECTION IN ORTHOPTERA

Earlier sections of this work featured discussions of (1) the techniques used in the study of food selection, (2) feeding in the groups and species of Orthoptera, and (3) the food categories selected by Orthoptera. These sections were based on data amassed during numerous field and laboratory studies. An evaluation of the reliability of these studies as a basis for conclusions on food selection seems appropriate. Such an evaluation requires an inquiry into the various factors which modify and determine food selection and the manner in which these agents operate.

Climate as a Factor in Food Selection

Climate, as well as microclimate, exert an influence on the feeding behavior of Orthoptera. Air and ground level heat, humidity, and wind act separately and together, both on the feeding insects and on the vegetation or animals on which they feed. The effects of these agents are modified by features of the topography and by density of the plant cover, which determine the degree to which the insects are sheltered.

Heat, Humidity, and Light.—Within the limits of their tolerance, insects, like other poikilotherms, become more active as the temperature rises. Up to a point, their feeding activities increase more or less in proportion to their body temperature (Gangwere, 1958), but, as shown in certain locusts (Hussein, 1937), restlessness and movement become so marked at the upper limits of their temperature tolerance that feeding diminishes or ceases. In an attempt to escape oppressive heat, individuals of *Nomadacris septemfasciata* regularly mount the vegetation and turn their bodies in order that the least possible surface is presented to the rays of the sun (Faure, 1935). Other locusts are known to do the same. Conversely, lowered temperatures cause lessened activities. Thus, many sun-loving grasshoppers become absolutely immobile during the night, and often they seek shelter under rocks and in cracks in the ground during cold weather. During the first cool autumn evening there is a marked decrease in the singing and other activities of nocturnal katydids and crickets. According to Walker (1937), *Grylloblatta,* which normally dwells under conditions of extremely low temperatures, needs food only once in three or four months and consumes less in a year than do many species in a day.

Rain operates both in the increase of humidity and as a mechanical factor. Thus, the sheer pounding of rain drops on insects, usually accompanied by increased velocity of wind, makes difficult their movements. Furthermore, insects are organisms of small size and, therefore, of comparatively large surface area with respect to volume. As a consequence, their bodies have a marked affinity for water, sometimes with fatal results. It should not surprise one to discover that most Orthoptera, like those observed here, probably cease feeding and seek shelter under leaves and other objects in their haunts during rainstorms. *Ischnoptera,* studied by Rau (1947), may offer a partial exception, for that author found that cockroaches of this genus maintain their positions atop vegetation during a drizzling rain.

The locust *Chortoicetes* moves into open fields from surrounding woodlands because of its positive phototaxis (Clark, 1950). The mere passage of a cloud obscuring the sun causes *Arphia sulphurea* and certain other oedipodines to cease movement (Gangwere, 1959a). The effects of the change in light are perhaps reinforced by an accompanying drop in body temperature resulting from the reduction in radiant energy. Similarly, many nocturnal Orthoptera are extremely sensitive to changes in light intensity. *Atlanticus testaceus,* for example, crouches when a beam of low intensity light is directed on it, and *Ceuthophilus* has proved to be at least equally sensitive to light (Gangwere, unpublished).

Daily variations in heat, humidity, and light control the daily rhythm of Orthoptera, including their feeding periodicity. On the latter subject there is a rather extensive literature. Parker's study on the two grasshoppers *Melanoplus b. bilituratus* and *Camnula pellucida* (1930) demonstrated the important role of temperature and humidity in regulation of feeding activities. The present author's paper on periodicity of feeding (1958) assembled some literature pertinent to the subject and described the three general patterns of periodicity found in Orthoptera, *viz.,* the diurnal, nocturnal, and incompletely nocturnal patterns.

Wind.—To a degree, wind operates somewhat independently of the above climatic agents. Hubbell (1936) discovered that *Ceuthophilus* is very sensitive to wind currents. Records by Shotwell (1930), Hastings (1948), and certain field observations made during this study indicate that feeding and movements of Orthoptera are depressed by excessive wind. Nevertheless, the role of this factor in modifying the animals' behavior, though it cannot be discounted, is probably not a major one.

For a detailed analysis of insects and climate the reader is referred to Uvarov's discussion (1931).

Food as a Factor in Food Selection

The attractiveness, availability, and condition of possible foods are factors which must be taken into account in studying the food selection of Orthoptera.

Attractiveness.—The attractiveness of a food is determined by the response of the feeder to the physical and chemical characteristics of that food. Some of the physical characteristics of food-plants are the comparative presence or absence of spines, dense pubescence, hard cuticle, thick leaves, and tough, fibrous tissues, which may make the food difficult or easy to approach, to bite into, or to chew. The role that toughness of leaves plays in food selection of acridids, particularly young ones, was discussed by Williams (1954). Bredemann (1941) found a certain maize and a sweet-corn with dense pubescence resistant to locusts, and Van der Merwe and Kent (1925) found stiff, succulent leaves resistant to *Zonocerus*. To the contrary, in this study, the prickly leaves of *Cirsium* (thistle) proved highly attractive to various grasshoppers, and the coarse, siliceous leaves of *Equisetum* (horsetail), though not a favorite, were often eaten by grasshoppers.

Essential oils, resinous substances, milky saps, and other chemical substances may make plants attractive or repulsive. One or another of the plant genera *Azadirachta, Calotropis, Melia,* and *Scylla* were noted by Bhatia (1940), Chauvin and Mentzer (1951), Roonwal (1953), Sergent and Poncet (1951), and Volkonsky (1937) as containing repulsive substances which inhibit feeding by various locusts; leaves of *Eucalyptus, Citrus* *nobilis*, *Papaver*, *Oleander*, and *Glycirrhiza* were found locust resistant by Bredemann (1941); and Williams (1954) suspected that the aromatic, resinous oils of the gymnosperm *Cupressus* act as a repellant to feeding by certain grasshoppers he studied. The latter may explain why, as noted in the present investigation, few Orthoptera eat gymnosperms.

In contrast, the grasshopper *Schistocerca ceratiola* feeds only on the odoriferous, highly resinous foliage of *Ceratiola ericoides* (Hubbell and Walker, 1928). Similar records are available for *Lea* (Hebard, 1941) and for a number of Orthoptera which feed on the sticky, pungent leaves of *Larrea* (Ball *et al*, 1942; Isely, 1944; Tinkham, 1944). Furthermore, various composites, milkweeds, and mints characterized by colored saps and special odors proved attractive to a wide assortment of grasshoppers, katydids, and crickets during the course of this study.

Succulence of foods is a factor in food selection. Flowers of forbs proved especially attractive to phaneropterines and various other Orthoptera in this study; lettuce, a food equal in succulence to flowers, proved to be almost a universal food; its relative *Lactuca* (wild lettuce) is especially attractive to many grasshoppers; and, in general, green, succulent vegetation is preferred by leaf-feeders to dried, brown leaves, though some exceptions are noted on pp. 113, 114. Nevertheless, water content does not always appear to be of major significance, for Roonwal's study of *Schistocerca* (1953) and Vuillaume's on *Zonocerus* (1953) showed no apparent correlation between preference value and water content.

Much of the difference in attractiveness of the food-plants tested in the present investigation probably depends on odor and taste, but the choice made between grasses and forbs is primarily a matter of the structure and texture of the leaves.

Carnivorous Orthoptera appear to be much less selective than are phytophagous species. As discussed in a preceding section of this report, mantids show practically no preferences, except those based on size of prey. It is possible, however, that a few butterflies and ants are repulsive and certain beetles so effectively armored that they may be immune to attack by mantids. In general, orthopteran carnivores eat the soft, succulent parts and leave untouched the wings, tarsi, and certain other hard parts. One must conclude, therefore, that palatability, mechanical characteristics, and succulence of food are factors in the selection of both plant and animal materials.

Availability.—The degree to which a given type of food is subjected to feeding is as much determined by its availability as by its attractiveness. An acceptable species, either plant or animal, may be present or absent, abundant or scarce, generally distributed or localized with respect to a given community. Thus, a plant absent from a community cannot be eaten there, though its preference value may be high. Furthermore, abundant plants are more likely to be eaten than are scarce ones, and plants uniformly distributed in a community are more likely to be fed upon, at least by generally distributed feeders, than are those localized in patches, though the plants may be present in equal numbers. This latter is explained by the fact that Orthoptera tend to eat the first acceptable food they encounter, instead of seeking more highly preferred ones. From this point-of-view, therefore, their choice of food may be said to be based in large part on chance encounter and availability.

Availability changes with the season, as various plants grow, mature, and die, and others take their places, and as particular plant parts, *e.g.*, flowers and fruits, appear and disappear. Among the Cyrtacanthacridinae, for example, there is a shift from grass-feeding in the spring to forb-feeding in late summer as annuals of this latter group become proportionately more available. Pfadt (1949a) observed a seasonal shift of food-plant in *Aulocara elliotti*. *Acrolophitus variegatus* and *Melanoplus texanus* may also be species whose periodism is linked with that of their food-plants (Isely, 1937).

Most species of Orthoptera were shown by the present feeding experiments to have food preferences which can seldom, if ever, be satisfied in nature because these foods are not present in the normal habitations of the feeders. Thus, countless species are fond of lettuce, a food they never encounter in nature. Similarly, the arid-land *Aeoloplides chenopodii,* whose normal food is saltbush and greasewood, is at certain times a pest on apple trees grown under irrigation (Wallace, 1955); caged *Hadrotettix trifasciatus* was reported by Isely (1938) to have fed entirely on two species of *Euphorbia* which do not occur in its habitat; two grasshoppers, *Melanoplus bivittatus* and *M. d. differentialis,* were found highly attracted to a citrus and a palm, neither of which grow in their normal habitation (Mail, 1931). Preferences for given plants, no matter how great they may be, are meaningless in their absence.

Carnivorous Orthoptera, as noted previously, are generally much less selective than are phytophagous species. Their diet tends, therefore, to be determined largely by food availability, which, in turn, depends on their habitat selection, on the periodism or seasonal availability of their prey, and on possible competition for their prey.

Size and Condition of Food.—The feeding of phytophagous species is regulated in part by differences in the physiological and developmental condition of their food-plants. Wilting and progressive seasonal desiccation reduce the acceptability of various plants to Michigan Orthoptera. Thus, *Agropyron,* a favorite of many acridids in spring and early summer, and *Bromus inermis,* the grains of which are eaten avidly by *Neoconocephalus* early in the season, are largely ignored in the fall as they become dry and brown. *Schistocerca obscura* undergoes a similar seasonal change in its food selection (Duck, 1944). In India, according to Husain, Mathur, and Roonwal (1946), *Capparis aphylla* is an important food of *Schistocerca gregaria* during middle summer but is unpalatable to this insect during late winter and early summer.

Developmental changes in plants influence feeding. As plants grow, they become increasingly inaccessible to ground-dwelling Orthoptera, and as their tissues become tougher and more fibrous they may become less attractive. Development of new parts accompanies growth and maturation of the food-plants. These parts may also be eaten but often are either more attractive or less attractive than are earlier parts. This latter agrees with Roonwal's conclusion (1953), *viz.,* if one part of a plant is acceptable, all parts are usually acceptable, but differentially so. It is not surprising, therefore, to find that there is an unusually high incidence of feeding by many species on the flowers of plants newly in bloom. Thus, *Conocephalus f. fasciatus,* a species seldom observed feeding in nature during this study, was once seen in large numbers eating the new flowers of *Agrostis.*

In the case of animal foods or prey, there are also physiological changes which modify the likelihood of feeding. The weakening of potential prey by oviposition, disease, hunger, etc., makes them more readily overpowered and eaten. This may explain in part the increased cannibalism noted among starved, caged orthopterans.

Size of prey is important. Small insects, including aphids and *Drosophila;* medium-sized ones, such as houseflies; and large ones, including blowflies and adult grasshoppers, are appropriate foods for, respectively, early instar, middle instar, and adult mantids (Didlake, 1926). This progression of size in food selection of predators would appear to be a general rule. Most attack the largest prey which they can overpower, and frequently they ignore smaller prey. The powerful *Saga,* as pointed out earlier, overcomes and eats the large carnivorous katydid *Tettigonia,* and mantids even eat small mammals and birds. In contrast, the voracious but much smaller *Oecanthus* eats mostly small, weak, soft-bodied aphids.

The Feeder as a Factor in Food Selection

Feeding behavior is markedly affected by the condition of the feeder, as determined by physiological, developmental, and other factors.

Hunger and Thirst.—The degree of hunger of a feeder is dependent on the length of time since its last meal, the amount eaten at that time, the rapidity with which digestion and elimination proceed, and the cumulative effect of recent meals. Selective responses to different foods diminish as hunger increases. Thus, starvation may alter normal feeding habits. The author's studies disclosed that *Chortophaga,* which is predominately a grass-feeder, will, when hungry, eat virtually any fresh forb which is offered; under pressure of starvation some strictly graminivorous acridines will eat sparingly of certain forbs, though they usually cannot survive on such a diet; certain acridids, normally phytophagous, become somewhat cannibalistic under starvation pressure; and, under these conditions, certain mildly predacious crickets develop marked cannibalism. Nevertheless, many species starve rather than eat foods different from those which they normally select in nature.

On the basis of earlier work (Gangwere, 1960b), it is believed that most Orthoptera usually do not drink in nature but obtain unbound water from their fresh, non-dry foods. Hence, a part of their changed response during starvation is probably the result of thirst. This contention is supported by statements by Bodine (1921), who found that grasshoppers, when starved, rapidly lose weight because of a reduction in the percentage of water in their body, and by Beier (1934), who noted that death from starvation is more delayed under conditions of high relative humidity than under those of low relative humidity. It follows that, when the weather is hot and dry and their foods become desiccated, many species become quite voracious and are attracted to anything moist, including earth, dampened cloth, and succulent foliage. *Acheta* (Criddle, 1925), various acridids (Williams, 1954; Shotwell, 1941), and *Chortoicetes* (Clark, 1947) will serve as examples.

Injury, Disease, and Parasitism.—Injury, disease, and parasitism presumably have their effect on the activities of Orthoptera, including their feeding, but the extent to which these factors operate and the manner in which they do so is not easy to demonstrate, except where the injury is severe or the disease or parasitism far advanced. The most common injury, loss of a leg, which is so frequent among the saltatorial forms, has no apparent effect on their feeding behavior and does not even seriously interfere with their motility.

Orthoptera are hosts of a considerable number of bacteria, protozoans, and entomogenous fungi, some of which are pathogenic to them. Observations on diseased and parasitized individuals are beyond the scope of the present study, but the work of others demonstrates that infection by some parasites has a pronounced effect on feeding. Numerous papers describing one or more aspects of parasitism and disease in various Orthoptera are available, and detailed discussions in cockroaches and in acridids were given by, respectively, Roth and Willis (1957) and Uvarov (1928). However, the material given below, except where indicated, is taken from Sweetman (1936) and Steinhaus (1946, 1952).

Many grasshoppers and some crickets are susceptible to certain strains of the bacterium *Coccobacillus acridiorum,* which sometimes causes epidemics in outbreak populations of the species of *Schistocerca.* Cannibalism under crowded conditions is believed to be partly responsible for creation of such epidemics. Susceptibility varies among different species of grasshoppers, and the virulence of different strains of the pathogen also varies and can be increased by passage. As the disease progresses, the host displays lessened and failing appetite and decreased activity, accompanied by rectal and oral discharge.

The most common of the fungi causing disease in Orthoptera is *Empusa grylli,* which attacks a wide range of species and sometimes causes epidemics among grasshoppers, especially under conditions of high density of population, high temperature, and high humidity. Often the first symptoms are lessened response to stimuli and reduced movement; later the insects may lose ability to maintain their equilibrium.

Among animal parasites, the gut-inhabiting Protozoa of the sporozoan group Gregarinida are especially characteristic of Orthoptera. Heavy infestations may produce debilitating disease, though they seldom cause death. Many roundworms parasitize Orthoptera. Some, like the nematode *Cephalobium microbivorum,* found in *Acheta,* live in the digestive tract, but others, such as the "hair-snakes" *Gordius* and *Paragordius* and the mermithids *Mermis* and *Agamermis,* occupy the body cavity or tissues of the host. The most common roundworm parasite of grasshoppers in the eastern United States is *Mermis subnigrescens.* During the present study, individuals of *Melanoplus k. luridus, M. bivittatus, M. s. scudderi, Orphulella speciosa,* and *Pseudopomala brachyptera* were found to be parasitized by mermithids, probably of the latter species. The larvae of various larvaevorid flies are also frequent parasites in grasshoppers and less often in katydids, camel crickets, and crickets.

The literature gives no obvious differences in feeding behavior of Orthoptera parasitized by roundworms or fly larvae in the earlier stages of development of the parasites, but, as the latter increase in size to the point of filling much of the body cavity, all of the functions of the host are deranged, and death accompanies or soon follows emergence of the parasites from its body.

Changes during Development.—Physiological changes accompanying growth, ecdysis, maturation of the gonads, the activities of courtship and mating, and old age have their effects on feeding.

Newly hatched young are generally unable to feed for a day or even longer after emergence, as has been shown in certain grasshoppers (Criddle, 1922; Valova, 1924; Van der Merwe and Kent, 1925), phasmids (Roth, 1917), and mantids (Gurney, 1951). In *Phyllium* (Leigh, 1909), there is a foodless period after hatching. It lasts for four days because it takes that long for the first-instar nymphs to climb from the ground, where the eggs are dropped, to the foliage of their food-plants. *Scapteriscus* may offer an exception to the above, for Hayslip (1943) and Van Zwaluwenburg (1918) reported that immatures of this mole cricket fight for food and begin feeding almost immediately after hatching.

It is generally accepted that Orthoptera do not feed immediately before, during, and after hatching. Muscle attachments are being shifted to the new exoskeleton; sclerites are hardening sufficiently to resist the pull of the muscles; and the mouthparts are not strong enough to be used in biting and chewing. Documentation of this point would appear unnecessary.

The feeding behavior of adult Orthoptera prior to the maturation of their testes and ovaries does not differ significantly from that of last-stage nymphs, but, with attainment of sexual maturity, the males, in particular, spend more time in sexual activity and less in feeding. While *in coitu,* males rarely, if ever, feed, and Ball (1915) noted that males of the grasshopper *Camnula pellucida* feed but little during the entire breeding period. The difference is less marked in the instance of females; many female grasshoppers and katydids of Michigan were found feeding considerably during copulation. However, this latter is partly offset by the fact that, at least in certain species, oviposition may inhibit feeding (Richards and Waloff, 1954) and may weaken them seriously (Melander and Yothers, 1917).

Advanced senescence of Orthoptera may be characterized by a gradual decrease in feeding until it ceases entirely, generally a few days before death. Rau and Rau (1913) reported that *Stagmomantis* consumes less and less food as old age is reached, and Roth (1917) found that *Carausius* may cease feeding for days at a time during old age.

Many of the changes in feeding behavior noted above, except for the last, are somewhat temporary in nature. Others, which are related to the insects' developmental polymorphism and their sexual dimorphism, are either longer in duration or progressive in nature. There is evidence to indicate the existence of a direct positive correlation between life stage and food consumption. Roth (1917) found that nymphs of the walking-stick *Carausius* double their food consumption in each successive stadium, and Langford (1930) noted that grasshopper nymphs almost double their consumption with each molt. The initial size difference between the first-stage nymphs of either sex is negligible, but it increases rapidly during growth, with a concomitant difference in the amount of food consumed. Females of the grasshopper *Melanoplus s. scudderi* consume more than do males, though they eat less per unit of weight (Gangwere, 1959). Females of certain grasshoppers eat 2.5 times more food than do males in a 12-hour period (Langford, 1930). Males of *Dichromorpha* are both shorter-lived and lighter eaters than are females (Rau, 1915), which is perhaps true for most Orthoptera. Males of certain grasshoppers feed for comparatively longer intervals of time, but females of these species feed more frequently (Williams, 1954).

Choice of food, as well as food consumption, may vary somewhat during the course of development. Among the strongly predacious mantids, as noted above, size and type of prey is roughly proportional to growth of the predator. Juvenile tree crickets (*Oecanthus*) are said to feed chiefly on aphids, while the adults are more herbivorous (Comstock, 1881; Parrott and Fulton, 1914; Riley, 1889). The opposite is true of *Forficula,* the immatures of which are more herbivorous than are adults (Crumb, Eide, and Bonn, 1941). The first-stage nymphs of the Moroccan locust in Transcaucasia feed almost exclusively on *Poa* *bulbosa,* but with each molt the number of food-plants increases (Sviridenko, 1924). *Zonocerus,* a polyphagous pyrgomorphine, exhibits distinct preferences which become somewhat less pronounced from stage to stage during nymphal development (Vuillaume, 1953). Early-stage juveniles of the walking-stick *Diapheromera femorata* eat basswood leaves but do not touch those of oak, which are preferred by late-stage nymphs and by adults (Graham, 1937). Furthermore, the early instars of most phytophagous grasshoppers and katydids of Michigan probably select leaves of more delicate texture than do adults.

In view of the above, it cannot be questioned that food selection and food consumption may vary somewhat during the life stages and between the sexes of certain species, though such disparities are not marked. Notwithstanding the above, the results of the present study show no really significant differences between the food-habits of nymphs, especially half-grown and larger ones, and those of adult males and females, aside from differences in consumption related to differences in body size. Information from a number of investigators, including Barnes (1955), Beall (1932), Chopard (1938), Didlake (1926), Faure (1935), and Williams (1954) supports the above view of essential uniformity of food selection throughout the life stages and between the sexes of Orthoptera. Such other differences as may exist in the feeding of a given species are the result of (1) changes in the seasonal aspect of the vegetation, which coincide with different stages in the life history, and of (2) changes in behavior consequent on the attainment of sexual maturity and, in most species, the acquisition of flight.

Other Factors Affecting the Feeders.—Habit patterns, conditioned acceptance of certain foods, and degree of crowding may modify food selection.

Habit patterns which affect feeding may take the form of habitat selection, migration, or mating. Each may operate to extend or to reduce the variety of possible food choices among the food-plants or prey available to the feeders. Some acridids occupy many different situations in several communities and in each of them have available a somewhat different assortment of food-plants; *Melanoplus f.-r. femur-rubrum* is such a species.

Other more localized species have a comparatively reduced assortment of food-plants or prey from which to select. Geophilous Orthoptera, for example, are restricted largely to foods growing close to the surface of the ground, ones which arboreal species seldom encounter; the food selection of the geophilous mantid *Litaneutria* is necessarily different from that of other mantids, which are phytophilous. In contrast, the phasmid *Diapheromera femorata* moves into the tops of trees because of a response to a strong negative geotaxis and, hence, is separated from a preferred food, the shrub *Rubus*. *Atlanticus testaceus*, an incompletely nocturnal shield-back geophilous during the day, undergoes a nocturnal ascent of the vegetation; its food selection during the night, the period when it does most of its feeding, is, therefore, basically that of a phytophilous species. Slender, laterally compressed acridids select growths of tall grasses and sedges for habitation and feeding and seldom come into contact with the short, procumbent grasses which occur in more open situations; more dorsoventrally depressed acridids live in areas of short, procumbent grasses and forbs and feed accordingly.

Williams (1954) investigated certain aspects of habitat selection. He found that grasshoppers are attracted to a number of visual patterns including vertical stripes, which probably explains why upright blades of grass are preferred to those lying flat; and that leaves in a vertical plane are easier to chew than those which are horizontal, which might explain part of the insects' preference for grasses over forbs.

Nymphs of *Romalea* migrate from their hatching sites to low, swampy land where there is more succulent vegetation on which to feed (Watson, 1941). Migration is more pronounced in certain highly noxious species. *Anabrus simplex, Camnula pellucida, Chortoicetes terminifera, Locusta migratoria, Melanoplus spretus, M. b. bilituratus, Nomadacris septemfasciata*, and *Schistocerca gregaria* are merely a few of the many Orthoptera which migrate in bands, both as immatures and as adults. In so doing, these wide-ranging insects encounter a much greater variety of food-plants than do many of their more restricted relatives.

Mating habits following sexual maturity may sometimes lead to a change in habitat. This latter is preeminently true of the plague locusts of the Old World, and in this country *Dissosteira longipennis* leaves its customary feeding grounds and migrates to breeding grounds where oviposition occurs (Corkins, 1923). Grouse locusts form seasonal mating aggregations (Cantrall, 1943), which habit may alter their available food assortment.

Mating may have other consequences. Copulation in mantids, as noted previously, is often accompanied by cannibalism, as the smaller male is eaten by the larger, stronger female. This seldom occurs at other times, when the males avoid the females. The same result was noted during copulation of *Ceuthophilus* (Turner, 1915) and *Grylloblatta* (Walker, 1937). It must also occur among certain of the voracious, carnivorous katydids.

The importance of conditioning in establishing particular food preferences has been noted in certain Lepidoptera and in other insects, but little is known of the extent to which it may operate in Orthoptera. Pfadt (1949) found that dandelion is a preferred food of *Melanoplus b. bilituratus* but detected no difference in the degree to which it is preferred among individuals captured in four different communities characterized by differences in vegetation. He concluded that conditioning does not exist in this species. In the present series of experiments, also, no evidence of conditioning was discovered, but tests were not devised to prove or to disprove its operation in the Michigan fauna. Sladden and Hewer (1938), however, reported an apparent transfer of induced food-habits from parent to young in the phasmid *Carausius*. Newly hatched nymphs descended from parents forced to eat ivy ate this plant more readily than did nymphs descended from parents fed on privet.

There is reason to believe that crowding in cages has a disturbing psychological effect on Orthoptera. Perhaps this explains, in part, the increased cannibalism that occurs among caged Orthoptera, particularly Tettigoniidae, even in the presence of ample food. It appears more likely, however, that the increased opportunities for cannibalism afforded by confinement and proximity of individuals account for this behavior. Crowding occurs under natural conditions in those species which occasionally or regularly increase to outbreak numbers, and under such conditions many of them commonly engage in cannibalism. The Mormon and Coulee crickets, various Old World plague locusts, *Tettigonia viridissima*, and the Rocky Mountain locust are some of the Orthoptera which have been recorded as eating others of their kind which were injured, diseased, or incapacitated by molting or oviposition. How much of the above should be attributed to starvation pressure and how much to the psychological effect of crowding is uncertain.

It is apparent from the foregoing that various factors regulate or, at least, influence food selection in Orthoptera. Variations in these factors are responsible for many minor discrepancies in the present data and in those recorded in the literature. Much of the uncertainty, however, has been cancelled out in the present investigation by the experimental design used. In planning the experiments and in evaluating their results, efforts were made to eliminate the influence of as many variables as possible and to make allowance for those which could not be controlled. Field observations were carried out over a long period, and careful records were kept of the conditions under which they were made. Feeding experiments were, as far as possible, repeated many times and under known conditions.

Thus, food selection was studied by the observation of individuals feeding in the field, by analyses of crop contents and fecal materials, and by differential feeding tests. The first two measure the choice of food made by the insects in their natural environments as a result of their food preferences, the availability of their foods, and other factors. The last of these methods measures only preferences, for availability and other environmental influences are cancelled out or equalized. Once conclusions were reached about the food-habits of a given species, they were checked against its structural adaptations for feeding. The resulting data, notwithstanding an expected variation, show a gratifying overall agreement sufficient to warrant the conclusion that food selection can be rather accurately measured through the use of several fairly simple techniques, each of which contributes in its own way to the end result.

SUMMARY AND CONCLUSIONS

1. A detailed survey of food selection in 76 species of Orthoptera (*sens. lat.*) of southeastern Michigan was carried out during the 1953 through 1955 and the 1957 through 1959 seasons. It involved the accumulation of feeding records in the insects' natural habitats, the use of differential feeding tests, the analysis of their crop contents and fecal materials, and the study of the structural adaptations of their mouthparts to foods. The strengths and weaknesses of these techniques are pointed out, and the results are critically reviewed in the light of an extensive literature.

2. Two methods of obtaining feeding records are described. A total of 300 feeding records for 48 species is listed. Descriptions are given of the more important localities at which feeding occurred, and remarks on the relative abundance, hence, availability, of food-plants are included in an appendix.

3. An improved method of carrying out differential feeding tests and of recording their results is given, along with a description of maintenance equipment and techniques. Data are given on tests involving 32 species of non-omnivorous Orthoptera. Omnivorous species were not studied in this manner, for they were considered so unselective as to be unproductive in tests of this type. An unusually large number of plant species, usually 30 to 50 or more, were used in the experiments on each species of Orthoptera, making possible a fairly comprehensive estimate of the total range of food preference of each. A number of the more abundant plants of the stations was also tested repeatedly in the cages of each orthopteran species to assure an accurate estimate of preference value.

4. The effective technique of analyzing crop contents and fecal materials to study food selection is described. Data are given on crop analyses of 58 species and on fecal analyses of 43 species.

5. The suitability of using mouthpart and other structural adaptations of Orthoptera as tools in the diagnosis of food selection is discussed. The technique used in the present study is described. The mouthparts, especially the mandibles, of Michigan Orthoptera are classified, and the distribution of these types in 64 species is given.

6. It is pointed out that feeding is so diversified in the Orthoptera as to defy description and that the only way in which it can be meaningfully discussed consists of examining it in individual families and subfamilies of the order, showing the full range of feeding in each and then generalizing about the habits of the majority. This is done for each of the major groups of Michigan, using data from the present study and reviewing it in the light of an extensive literature. Based on this discussion, the primary and secondary, if any, food-habits of the groups are summarized in Table IV.

7. The food-habits among species of a subfamily are most often rather similar and tend to be unlike those of species belonging to other groups, even related ones. Nevertheless, there may be considerable overlap between the food-habits of different subfamilies.

8. It appears that most groups of Orthoptera are polyphagous, sometimes to the point of omnivory. Only a few isolated species and genera of herbivores are oligophagous or monophagous.

9. The most widespread type of food-habit is the omnivorous, for approximately one-half of the groups studied are either omnivorous or modified omnivorous. These scavengers usually eat whatever is available in the way of dead or decomposing plant and animal materials but often may take living materials. Despite the marked latitude which characterizes their feeding behavior, most omnivores tend to specialize somewhat in one or more major food categories, though capable of selecting more widely. Field crickets, for example, tend toward herbivory, though they eat a wide assortment of both plant and animal materials.

10. The herbivores among the Orthoptera show definite, consistent preferences. They usually specialize in a single category of food, *e.g.*, grasses or forbs, but select widely within the category. A wide variety of plants, including rushes, horsetails, ferns, mosses, lichens, fungi, and algae, and especially forbs, grasses, sedges, and woody trees, vines, and shrubs is taken. All parts of these plants, including roots, stems, and especially leaves and flowers, are eaten.

11. Predation is common in the Orthoptera. The weaker predators, which are not usually voracious, eat many kinds of small, soft-bodied insects. In contrast, the powerful predators, like mantids, show practically no preferences and rapaciously eat almost any insect of suitable size which they can catch and overpower, including members of their own species. Some predators pursue their prey; some stalk it; others lie in wait for it to move close enough for capture. Teneral, injured, or weakened prey are often taken by predacious Orthoptera and sometimes by groups not normally predacious. This latter type of food selection, the eating of weakened prey, is somewhat intermediate between true predation and scavenging.

12. Even a cursory examination of data given in this study reveals that food-habits are probably not suitable for diagnostic use in taxonomic separation of closely related species of Orthoptera, for there is generally too little difference between their food selection. Nevertheless, it is possible that there are instances in which food-habits can be used as indicators of adaptive radiation, though no such case was uncovered in this study.

13. On the basis of the demonstrated latitude of food selection in most groups and species of Orthoptera and in view of the general availability of their common food-plants and prey in most of their habitations, it is concluded that food probably plays only a minor part in the insects' habitat selection. The few monophagous or oligophagous species encountered, species necessarily restricted to areas in which their host plants grow, are doubtlessly exceptions.

14. The results of the investigation are in general agreement with those of the only comparable work, Isely's pioneering studies on Texas Acrididae and Tettigoniidae, but are based on a different fauna and are more comprehensive and much wider in scope, treating representatives of all major groups of Orthoptera of the eastern United States and using certain methods he did not use.

15. The categories of food taken by Orthoptera are classified and discussed. They include (1) plant products, (2) dead plant materials, (3) living plants, (4) animal products, wastes, and secretions, (5) dead animal materials, and (6) living animals. Groups and species of Orthoptera selecting each of these foods are listed.

16. Many Orthoptera accept dead, dried vegetable materials of a type they do not ordinarily eat in the living, green condition. This suggests that some of the specificity that grasshoppers and allies exhibit in their food selection may be lost upon the death and desiccation of their food-plants.

17. It is noted that numerous interrelated factors regulate or, at least, influence food selection in Orthoptera and that these factors are responsible for minor discrepancies in the data of the present investigation. Factors relative to the climate, to the food, and to the feeder are listed. Climate is a modifying agent through changes in heat, light, humidity, and wind, as altered by cover. Food varies in its attractiveness, in its availability, in its size, and in its developmental and physiological condition. The feeder, too, varies in a number of ways which influence the course of its food selection. It varies physiologically in terms of hunger, thirst, injury, disease, and parasitism; developmentally in terms of hatching, size, molting, sexual maturity, and senescence; and in relation to other factors, including habit patterns, conditioning to food, and degree of crowding.

18. In general, the food-habits of different life stages of a given species are found to be similar, though sometimes influenced by seasonal changes in food availability and condition. Developmental changes in size, condition, and habits of the feeder may also alter food selection.

19. The food-habits of the two sexes, like those of different life stages of the same species, are found to be similar.

20. The latitude of food selection in Orthoptera tends to be enhanced under conditions of starvation pressure. Nevertheless, many species willingly starve rather than eat foods different from those which they normally select in nature.

21. Some Orthoptera have great preference for foods, both animal and plant, not normally found in their environments. Lettuce, for example, is almost a universal food for Orthoptera. Only certain seminivores, carnivores, and graminivores reject it.

22. Notwithstanding the complexity of food selection and the pitfalls inherent in the study of it, the data of this investigation show a gratifying overall agreement, which indicates that each of the above techiques of study is valuable and reliable when

used with discretion. Food selection, therefore, can be rather accurately measured through the use of a number of fairly simple methods, each of which contributes in its own way to the end result.

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REFERENCES

The literature on food selection in Orthoptera is vast and unwieldy. It is relatively difficult to find, for it usually comprises but incidental parts of larger studies on other subjects, and its papers are widely scattered throughout numerous, often obscure ecologic, economic, taxonomic, and other journals, both private and governmental, in a host of languages. Much of it is repetitious and relates largely to the control of the numerous noxious species in the order, particularly earwigs, cockroaches, crickets, and plague locusts. This segment of the literature, of which the valuable publications of the Anti-Locust Research Centre are an outstanding exception, is sometimes useless as a source of basic information. Nevertheless, the extensiveness of the literature assures the presence of a considerable amount of worthwhile information, providing one can locate it.

On the basis of the foregoing, it is apparent that it is a difficult undertaking to survey the literature dealing with food selection even in a given family, and it is a practical impossibility to do so for the Orthoptera as a whole. Hence, the following bibliography is offered with no pretense of completeness, though it is hoped that it presents a reasonable coverage of the salient literature. It includes only those works cited in this report, which have been examined personally by the author, and represents but a fraction of the total he has perused over the last eight years. It necessarily excludes many valuable studies which duplicate those already cited and presents other less-significant ones which document points developed in the text.

An asterisk following a reference indicates that the reference was seen in abstract form only.

ABBOTT, C. E. 1944. Cannibalism in herbivorous insects. Bull. Brooklyn Ent. Soc., 39: 82.

AGRAWAL, N. S. 1955. Bionomics of *Atractomorpha crenulata* Fab. Indian Jour. Ent., 17: 230–240.

AKERMAN, C. 1932. On the carnivorous habits of the long-horned grasshopper, *Clonia vittata* Thunberg. Ann. Natal Mus., 7: 143–144.

ALLRED, B. W. 1941. Grasshoppers and their effect on sagebrush on the Little Powder River in Wyoming and Montana. Ecology, 22: 387–392.

ANDERSON, N. L., and J. C. WRIGHT. 1952. Grasshopper investigations on Montana range lands. Bull. Montana Agric. Exp. Sta., 486: 46 pp.

BAILEY, V. 1928. Animal life of the Carlsbad Cavern. Mon. Amer. Soc. Mammal., 3: xiii + 195 pp.

BALDUF, W. V. 1943. New food records of entomophagous insects. Ent. News, 54: 12–15.

BALL, E. D. 1915. How to control the grasshoppers. Bull. Utah Agric. Exp. Sta., 138: 79–116.

————. 1936. Food plants of some Arizona grasshoppers. Jour. Econ. Ent., 29: 679–684.

BALL, E. D., E. R. TINKHAM, R. FLOCK, and C. T. VORHIES. 1942. The grasshoppers and other Orthoptera of Arizona. Tech. Bull. Arizona Agric. Exp. Sta., 93: 255–373.

BANTA, A. M. 1907. The fauna of Mayfield's Cave. Publ. Carnegie Inst. Washington, 67: 1–114.

BARLOW, E. 1895. A short note on the food insects of the mantis *Hierodula bipapilla* Serv. Proc. Asiatic Soc. Bengal: 138–139.

BARNES, O. L. 1955. Effect of food plants on the lesser migratory grasshopper. Jour. Econ. Ent., 48: 119–124.

BARRETT, O. W. 1902. The changa, or mole cricket (*Scapteriscus didactylus* Latr.) in Porto Rico. Bull. Porto Rico Agric. Exp. Sta., 2: 1–19.

BAUMGARTNER, W. J. 1911. Observations on the Gryllidae: III. Notes on the classification and on some habits of certain crickets. Sci. Bull. Kansas Univ., 5: 309–319.

BEALL, G. 1929. Observations on the ant cricket. Proc. British Columbia Ent. Soc., 26: 44–46.

————. 1932. The life history and behavior of the European earwig, *Forficula auricularia* L. in British Columbia. Proc. British Columbia Ent. Soc., 29: 28–43.

BEEBE, W., and R. KENEDY. 1957. Habits, palatability and mimicry in thirteen Ctenuchid moth species from Trinidad, B. W. I. Zoologica, 42: 147–158.

BEIER, M. 1933, 1934. Orthopteroidea I, II (Mantodea with J. Jaus). Biologie der Tiere Deutschlands. Teil 26, Lief 36, 37: 415 pp.

BEIER, M., and F. HEIKERTINGER. 1952. Fangheuschrecken. Neue Brehm-Bücherei, Leipzig, 64: 1–32.

BENNETT, C. B. 1904. Earwigs (*Anisolabia maritima* Bon.). Psyche, 11: 47–53.

BÉRENQUIER, P. 1905. Notes orthoptérologiques. I. La Magicienne dentelée *"Saga serrata."* Bull. Soc. Et. Sc. nat. Nimes: 145–154.

BERLAND, L. 1929. Les Forficules sont-elles carnivores? Bull. Soc. ent. Fr.: 289–290.

BEUTENMÜLLER, W. 1894. Descriptive catalog of the Orthoptera found within fifty miles of New York City. Bull. Amer. Mus. Nat. Hist., 6: 253–316.

BHATIA, D. R. 1940. Observations on the biology of the desert locust (*Schistocerca gregaria* Forsk.) in Sind-Rajputana desert area. 1. The preferred food plants of the locust. Indian Jour. Ent., 2: 187–192.

BHATIA, D. R., and H. L. SIKKA. 1956. Some striking cases of food preference by the desert locust (*Schistocerca gregaria* Forsk.). Indian Jour. Ent., 18: 205–210.

BLATCHLEY, W. S. 1920. Orthoptera of northeastern America with especial reference to the faunas of Indiana and Florida. Nature Publ. Co., Indianapolis: 784 pp.

BODINE, J. N. 1921. Factors influencing the water content and the rate of metabolism of certain Orthoptera. Jour. Exp. Zool., 32: 137–164.

BOETTGER, C. R. 1950. Die Gewächshausheuschrecke (*Tachycines asynamorous* Adelung). Abhandl. Braunschweigischen Wiss. Gesell., Bd. II: 13–39.

BOLDYREV, B. T. 1928. Biological studies on *Bradyporus multituberculatus* F. W. Eos, 4: 13–56.

BREDEMANN, G. 1941. Über die Züchtung heuschrecken-resistentes Pflanzen. Zeit. Pflanzenkrankh., 51: 337–342.

BRELAND, O. P. 1941. Notes on the biology of *Stagmomantis carolina* (Joh.). Bull. Brooklyn Ent. Soc., 36: 170–177.

BRINDLEY, H. H. 1918. Notes on certain parasites, food, and capture by birds of the common earwig (*Forficula auricularia*). Proc. Cambridge Phil. Soc., 19: 167–177.

BROOKS, A. R. 1958. Acridoidea of Southern Alberta, Saskatchewan, and Manitoba. Canad. Ent., 90, suppl. 9: 92 pp.

BROWN, C. A. R. 1899. A bird killed by a mantis. Jour. Bombay Nat. Hist. Soc., 12: 578–579.

BURMEISTER, H. 1864. Notiz über die Mantis-arten bei Buenos-Aires. Berliner ent. Zeit.: 234–238.

BURR, M., B. P. CAMPBELL, and B. P. UVAROV. 1923. A contribution to our knowledge of the Orthoptera of Macedonia. Trans. Roy. Ent. Soc. London: 110–169.

CANTRALL, I. J. 1943. The ecology of the Orthoptera and Dermaptera of the George Reserve, Michigan. Misc. Publ. Univ. Michigan Mus. Zool., 54: 182 pp.

CAROTHERS, E. E. 1923. Notes on the taxonomy, development and life history of certain Acrididae. Trans. Amer. Ent. Soc., 49: 7–24.

CAUDELL, A. N. 1902. A greedy insect. Ent. News, 13: 60.

———. 1904. Injury by a cricket in the South. Bull. U. S. Dept. Agric. Div. Ent., 44: 88–89.

———. 1908. *Gryllodes sigillatus* Walker (= *poeyi* Sauss.) in Washington, D. C. Psyche, 15: 96.

———. 1921. On the orthopterous group Phaneropterae (= Scudderiae), with descriptions of a new genus and species. Jour. Washington Acad. Sci., 11: 487–493.

———. 1925. *Pycnoscelus surinamensis* Linnaeus (Orthop.); on its nymphs and the damage it does to rose bushes. Proc. Ent. Soc. Washington, 27: 154–157.

CHAPMAN, R. F. 1957. Observations on the feeding of adults of the red locust (*Nomadacris septemfasciata*) (Serville). British Jour. Animal Behavior, 5: 60–75.

CHAUVIN, R., and C. MENTZER. 1951. Contribution à l'étude des substances naturelles et de synthèse répulsives pour les Acridiens. Bull. Off. nat. Anti-acrid., 1: 5–14.

CHITTENDEN, F. H. 1903. Some insects recently injurious to truck crops. Bull. U. S. Dept. Agric. Div. Ent., 40 (N. S.): 113–120.

CHOPARD, L. 1938. La biologie des Orthoptères, Encyclopédie Entomologique. Paul Lechevalier, Paris: 541 pp.

———. 1946. Quelques notes sur les moeurs de *Saga*. Bull. Soc. ent. Fr., 9: 126–128.

CLARK, E. J. 1948. Studies in the ecology of British grasshoppers. Trans. Roy. Ent. Soc. London, 99: 173–222.

CLARK, L. R. 1947. An ecological study of the Australian plague locust (*Chortoicetes terminifera* Walk.) in the Bogan-Macquarie outbreak area, N. S. W. Bull. Commonwealth Australia Council Sci. Indust. Res., 226: 1–71.

———. 1950. On the abundance of the Australian plague locust in relation to the presence of trees. Australian Jour. Agric. Res., 1: 64–75.

CLAUSEN, C. P. 1940. Entomophagous insects. McGraw-Hill Publ. Co., London: x + 688 pp.

CLEVELAND, L. R. 1934. The wood-feeding roach *Cryptocercus*, its protozoa, and the symbiosis between protozoa and roach. Mem. Amer. Acad. Arts Sci., 17: 185–342.

COMSTOCK, J. H. 1881. The snowy tree cricket (*Oecanthus niveus* H.). Rept. Ent., Rept. Comm. Agric., U. S. Dept. Agric., for 1880: 271–272.

COQUILLETT, D. W. 1886. Report on the locusts of the San Joaquin Valley, California. In: Riley, C. V., Rept. Ent., Rept. Comm. Agric., U. S. Dept. Agric., for 1885: 289–303.

CORKINS, C. L. 1923. Mormon cricket control. Circ. Colorado Agric. Coll., 40: 1–20.

CRAIGHEAD, F. C. 1950. Insect enemies of eastern forests. Misc. Publ. U. S. Dept. Agric., 657: 679 pp.

CRIDDLE, N. E. 1922. Manitoba grasshoppers. Canad. Field-Nat., 36: 41–44, 66–68.

———. 1925. Field crickets in Manitoba. Canad. Ent., 57: 79–84.

———. 1933. Studies in the biology of N. Amer. Acrididae development and habits. Proc. World's Grain Exhib. Conf. Reprint Canad. Soc. Tech. Agric., 2: 474–494.

CRUMB, S. E., P. M. EIDE, and A. E. BONN. 1941. The European earwig. Tech. Bull. U. S. Dept. Agric., 766: 1–76.

DAVIDSON, J. F. 1943. An occurrence of *Scudderia furcata furcata* Brunner, on the coast of British Columbia. Proc. British Columbia Ent. Soc., 40: 31–32.

DAVIS, W. T. 1893. The song of *Thyreonotus* (*Atlanticus*). Canad. Ent., 25: 108–109.

———. 1889. List of the Orthoptera found on Staten Island. Ent. Amer., 5: 78–81.

———. 1912. An injurious grasshopper at Ridgeway, N. J. Ent. News, 23: 2–3.

———. 1912a. Three new species of *Belocephalus* from Florida. Jour. N. York Ent. Soc., 20: 122–125.

———. 1914. Notes on Orthoptera from E. Coast of Florida with descriptions of two new species of *Belocephalus*. Jour. N. York Ent. Soc., 22: 191–205.

———. 1923. A new walking-stick insect from eastern North America. Jour. N. York Ent. Soc., 31: 52–55.

DECOURSEY, R. M. 1951. The European mantis, *Mantis religiosa* (Linne), in Connecticut. Psyche, 58: 158.

DIDLAKE, M. 1926. Observations on the life-histories of two species of praying mantis. Ent. News, 37: 169–174.

DIMMOCK, G. 1884. (*Forficula auricularia* as an enemy of *Pulex*). Psyche, 4: 186.

DUCK, L. G. 1944. The bionomics of *Schistocerca obscura* (Fabr.). Jour. Kansas Ent. Soc., 17: 105–119.

EVANS, F. C., and E. DAHL. 1955. The vegetational structure of an abandoned field in southeastern Michigan and its relation to environmental factors. Ecology, 36: 685–706.

FAURE, J. C. 1935. The life history of the red locust (*Nomadacris septemfasciata* (Serville)). For. Bull. Union S. Africa Dept. Agric., 144: 1–32.

FERNALD, M. L. 1950. Gray's manual of botany, eighth ed. American Book Co., N. York: lxiv + 1632 pp.

FOLSOM, J. W. 1931. Damage to cotton by crickets. Jour. Econ. Ent., 24: 807–815.

FOLSOM, J. W., and P. A. WOKE. 1939. The field cricket in relation to the cotton plant in Louisiana. Tech. Bull. U. S. Dept. Agric., 642: 1–28.

FORBES, S. A. 1905. Noxious and beneficial insects of the state of Illinois. Rept. Illinois St. Ent., 23: 273 pp.

Frank, M. E. 1930. An observation on the diet of the praying mantis. Lingnan Sci. Jour., 9: 321–322.

Froggatt, W. W. 1905. Stick or leaf insects. Agric. Gaz. N. S. Wales, 862: 1–6.

Frohawk, F. W. 1940. Earwigs destroying larvae. The Ent., 73: 38.

Fry, H. J. 1927. Grasshopper culture in the laboratory. Jour. N. York Ent. Soc., 35: 41–50.

Fulton, B. B. 1915. The tree crickets of New York: life history and bionomics. Tech. Bull. N. York Agric. Exp. Sta., 42: 1–47.

————. 1924. The European earwig. Bull. Oregon Agric. Exp. Sta., 207: 1–29.

————. 1926. The tree crickets of Oregon. Bull. Oregon Agric. Exp. Sta., 223: 1–20.

————. 1927. Concerning some published statements on the habits of the European earwig. Ent. News, 38: 272–273.

————. 1930. Notes on Oregon Orthoptera with descriptions of new species and races. Ann. Ent. Soc. Amer., 23: 611–641.

Gangwere, S. K. 1958. Notes on the feeding periodicity of various Orthoptera. Papers Michigan Acad. Sci., Arts, Letters, 43: 119–132.

————. 1959. Experiments upon the food consumption of the grasshopper *Melanoplus s. scudderi* (Uhler). Papers Michigan Acad. Sci., Arts, Letters, 44: 93–96.

————. 1959a. A comparative study on the food-habits of *Arphia sulphurea* (Fabricius) and *Atlanticus testaceus* (Scudder). Rept. Grant No. 2408, Penrose Fund, Yearbook Amer. Phil. Soc.: 233–236.

————. 1960. The feeding and culturing of Orthoptera in the laboratory. Ent. News, 71: 7–45.

————. 1960a. The use of the mouthparts of Orthoptera during feeding. Ent. News, 71: 193–206.

————. 1960b. Notes on drinking and the need for water in Orthoptera. Canad. Ent., 92: 911–915.

————. 1962. A comparative study of the structural adaptations of mouthparts for feeding (Orthoptera, *sens. lat.*). In press.

————. 1962a. The mechanical handling of food by the alimentary canal of Orthoptera. In press.

Gates, M. F. 1912. Roaches and their extermination by the use of sodium fluorid (NaF). U. S. Naval Med. Bull., 6: 212–214.

Ghosh, C. C. 1912. The big brown cricket (*Brachytrypes achatinus* Stol). Ent. Ser. Mem. Dept. Agric. India, 4: 161–182.

Gier, H. T. 1947. Growth rate in the cockroach *Periplaneta americana* (Linn.). Ann. Ent. Soc. Amer., 40: 303–317.

Gillette, C. P., and S. A. Johnson. 1905. The western cricket. Bull. Colorado Agric. Exp. Sta., 101: 16 pp.

Goe, M. T. 1925. Eight months study of earwigs. Ent. News, 36: 234–238.

————. 1928. Concerning earwigs. Ent. News, 39: 62.

GOLDING, F. D. 1935. Notes on the food-plants of Nigerian insects. Bull. Ent. Res., 26: 263–265.

———. 1937. Notes on the food-plants of Nigerian insects. Bull. Ent. Res., 28: 5–9.

———. 1940. Notes on the food-plants of Nigerian insects. Bull. Ent. Res., 31: 127–130.

GOULD, G. E., and H. O. DEAY. 1938. Notes on the bionomics of roaches inhabiting houses. Proc. Indiana Acad. Sci., 47: 281–284.

GOWDEY, C. C. 1923. The principal agricultural pests of Jamaica. Ent. Bull. Dept. Agric. Jamaica, 2: vi + 80 pp.

GRAHAM, S. A. 1937. The walking stick as a forest defoliator. Circ. Univ. Michigan School For. Conserv., 3: 1–28.

GRASSÉ, P. P. 1922. Étude biologique sur le criquet Égyptien (*Orthacanthacris aegyptia* L.). Bull. Biol. France Belgique, 56: 545–578.

GREEN, E. E. 1909. The cockroach as a predatory insect. Spolia Zelan., 6: 135.

GRIFFITH, H. G. 1882. Carnivorous habits of *Microcentrus retinervis*. Amer. Nat., 16: 408.

GRIMPE, G. 1921. Beiträge zur Biologie von *Phyllium bioculatum* G. R. Gray. Zool. Jahr., 44: 227–266.

GRINFELD, E. K. 1957. The feeding of the grasshoppers (Orthoptera, Tettigonioidea) on pollen of flowers and their possible significance in the origin of entomophily in plants. Ent. Obzr., 36: 619–624.

GURNEY, A. B. 1951. Praying mantids of the United States: native and introduced. Rept. Smithsonian Inst. Washington, 1950: 339–362.

———. 1953. Recent advances in the taxonomy and distribution of *Grylloblatta*. Jour. Washington Acad. Sci., 43: 325–332.

HADDEN, F. C. 1927. A list of insects eaten by the mantis *Paratenodera sinensis* (Saussure). Proc. Hawaiian Ent. Soc., 6: 385–386.

HAFEZ, M., and M. M. IBRAHIM. 1958. Ecological and biological studies on *Acrida pellucida* Klug, in Egypt. Bull. Soc. ent. Égypte, 42: 163–181.

HANCOCK, J. L. 1898. The food habits of the Tettigidae. Ent. Record, 10: 6–7.

———. 1902. The Tettigidae of North America. Privately publ., Chicago: vii + 188 pp.

———. 1904. Oviposition and carnivorous habits of the green meadow grasshoppers (*Orchelimum glaberrimum*). Psyche, 11: 69–71.

HASTINGS, E. 1948. Report on grasshopper research. Part I. Report of states—1947. Mimeographed release Montana Agric. Exp. Sta.: 1–10.

HAWKER-SMITH, W. 1943. The food of the earwig. The Ent., 76: 63–64.

HAYSLIP, N. C. 1943. Notes on biological studies of mole crickets at Plant City, Florida. Florida Ent., 26: 33–46.

HEBARD, M. 1917. The Blattidae of North America north of the Mexican boundary. Mem. Amer. Ent. Soc., 2: vi + 284 pp.

HEBARD, M. 1918. New genera and species of Melanopli found within the United States. Trans. Amer. Ent. Soc., 44: 141–169.

————. 1925. The North American genus *Inscudderia*. Trans. Amer. Ent. Soc., 51: 321–330.

————. 1941. The group Pterophyllae as found in the United States. Trans. Amer. Ent. Soc., 67: 197–219.

HETRICK, L. A. 1949. Field notes on a color variant of the two-striped walking-stick, *Anisomorpha buprestoides* (Stoll). Florida Ent., 32: 74–77.

HOUGHTON, C. O. 1904. An unusual injury by the snowy tree-cricket and notes on its feeding habits. Ent. News, 15: 57–61.

————. 1909. Notes on *Oecanthus*. Canad. Ent., 41: 113–115.

HOWARD, L. O. 1886. The excessive voracity of the female mantis. Science, 8: 326.

HOWARD, L. O., and C. L. MARLATT. 1902. The principal household insects of the United States with a chapter on insects affecting dry vegetable foods by F. H. Chittenden. Bull. U. S. Dept. Agric. Div. Ent., 4 (N. S.): 1–131.

HUBBELL, T. H. 1936. A monographic revision of the genus *Ceuthophilus*. Biol. Sci. Ser. Publ. Univ. Florida, 2: 551 pp.

————. 1960. The sibling species of the Alutacea Group of the bird-locust genus *Schistocerca*. Misc. Publ. Univ. Michigan Mus. Zool., 116: 91 pp.

HUBBELL, T. H., and I. J. CANTRALL. 1938. A new species of *Appalachia* from Michigan. Occ. Papers Univ. Michigan Mus. Zool., 389: 1–22.

HUBBELL, T. H., and F. W. WALKER. 1928. A new shrub-inhabiting species of *Schistocerca* from Central Florida. Occ. Papers Univ. Michigan Mus. Zool., 197: 1–10.

HUSAIN, M. A., C. B. MATHUR, and M. L. ROONWAL. 1946. Studies on *Schistocerca gregaria* (Forskal). XIII. Food and feeding habits of the desert locust. Indian Jour. Ent., 8: 141–163.

HUSSEIN, M. 1937. The effect of temperature on locust activity. Bull. Tech. Sci. Serv. Minist. Agric. Egypt, 184: 55 pp.

ILLINGWORTH, J. F. 1929. Grasshoppers eat pine-apple mealy bugs and other pests. Proc. Hawaiian Ent. Soc., 7: 256–257.

ISELY, F. B. 1937. Seasonal succession, soil relations, numbers, and regional distribution of northeastern Texas acridians. Ecol. Mon., 7: 318–344.

————. 1938. The relations of Texas Acrididae to plants and soils. Ecol. Mon., 8: 551–604.

————. 1941. Researches concerning Texas Tettigoniidae. Ecol. Mon., 11: 457–475.

————. 1944. Correlation between mandibular morphology and food specificity in grasshoppers. Ann. Ent. Soc. Amer., 37: 47–67.

————. 1946. Differential feeding in relation to local distribution of grasshoppers. Ecology, 27: 128–138.

ISELY, F. B., and G. ALEXANDER. 1949. Analysis of insect food habits by crop examination. Science, 109: 115–116.

JAMES, H. G. 1945. A note on the mortality of *Mantis religiosa* L. in the egg stage. 75th Ann. Rept. Ent. Soc. Ontario, 1944: 35–37.

JAMES, M. T. 1932. The rôle of cannibalism in the spread of fungous diseases of grasshoppers. Science, 75: 266.

JOHNSTON, H. B. 1924. A note on locusts. Sudan Notes Records, 7: 91–101.

JORDAN, K. 1909. Notes on the anatomy of *Hemimerus talpoides*. Novit. Zool., 16: 327–330.

JOYCE, R. J. V. 1952. The ecology of grasshoppers in East Central Sudan. Anti-Locust Bull. Anti-Locust Res. Centre, 11: 1–99.

KATÔ, M. 1940. Feeding activity of a grasshopper, *Prumna* sp., widely distributed at Mts. Hakkôda. Sci. Rept. Tôhoku Imp. Univ., Biol., 15: 191–201.

KEMPER, H. 1937. Beobachtungen über die Biologie der Hausgrille (*Gryllus domesticus* L.). Zeit. hyg. Zool., 29: 69–86.

KNOWLTON, G. F. 1947. Snowy tree cricket eats pea aphids. Bull. Brooklyn Ent. Soc., 42: 142.

KNOWLTON, G. F., and R. S. ROBERTS. 1943. *Orchelimum* feeding notes. Bull. Brooklyn Ent. Soc., 38: 140–141.

KÖRTING, A. 1934. Über den Einfluss der Nahrung auf das Wachstum der Stabheuschrecke. Zeit. wiss. Insektenbiol., 27: 48–53.

LA BAUME, W. 1918. In: Bücher *et al.:* Die Heuschreckenplage und ihre Bekämpfung. Mon. angew. Ent., 3: 274 pp.*

LANGFORD, G. S. 1930. Some factors relating to the feeding habits of grasshoppers, with special reference to *Melanoplus bivittatus*. Bull. Colorado Agric. Exp. Sta., 354: 1–53.

LA RIVERS, I. 1944. A summary of the Mormon cricket (*Anabrus simplex*). Ent. News, 55: 71–77, 97–102.

LAURENT, P. 1933. *Mantis* captures hummingbird. Ent. News, 44: 39.

LEIGH, H. S. 1909. Preliminary account of the life-history of the leaf-insect, *Phyllium crurifolium* Serville. Proc. Roy. Zool. Soc. London: 103–112.

LUGGER, O. 1898. The Orthoptera of Minnesota. Bull. Minnesota Agric. Exp. Sta., 55: 1–296.

LÜSTNER, G. 1914. Die Nahrung des Ohrwurmes (*Forficula auricularia* L.) nach dem Inhalt seines Kropfes. Centr. Bakt. Parasit., Abt. 2 (40): 482–514.

MACLAGAN, D. S. 1932. An ecological study of the "Lucerne flea" (*Smynthurus viridis,* Linn.)—I, II. Bull. Ent. Res., 23: 101–145, 151–190.

MAIL, G. A. 1931. Food preferences of grasshoppers. Jour. Econ. Ent., 24: 767–768.

MARUCCI, P. E. 1955. Notes on the predatory habits and life cycle of two Hawaiian earwigs. Proc. Hawaiian Ent. Soc., 15: 565–569.

MATHUR, R. N. 1934. On the biology of the Mantidae, with notes by C. F. C. Beeson and S. N. Chatterjee. Ent. Ser. Indian For. Records, 20: 1–25.

McCOLLOCH, J. W. 1915. A cricket predacious on the termite. Jour. Econ. Ent., 8: 308.

McLEOD, J. H., and D. A. CHANT. 1952. Notes on the parasitism and food habits of the European earwig, *Forficula auricularia* L. Canad. Ent., 84: 343–345.

MELANDER, A. L., and M. A. YOTHERS. 1917. The coulee cricket. Bull. Washington Agric. Exp. Sta., 137: 1–56.

METCALF, C. L., and A. S. COLBY. 1930. The meadow grasshopper, *Orchelimum vulgare* Harris, a new raspberry pest. Jour. Econ. Ent., 23: 97–108.

MIALL, L. C., and A. DENNY. 1886. The structure and life-history of the cockroach (*Periplaneta orientalis*). London: 224 pp.

MONTI, S. C. R. 1902. Contributo alla conoscenza della *Dolichopoda geniculata* (O. G. Costa). Nota prima. Rend. R. Inst. Lombardo Sci. Lettere, (2)(35): 470–491.

MORE, J. D. 1924. The mole cricket (*Scapteriscus vicinus* Latr.). Bull. Georgia Agric. Exp. Sta., 101 (rev.): 3–12.

MORSE, A. P. 1916. A New England orthopteran adventive. Psyche, 23: 178–180.

————. 1920. Manual of the Orthoptera of New England, including the locusts, grasshoppers, crickets, and their allies. Proc. Boston Nat. Hist. Soc., 35: 197–556.

MOURGUE, M. 1909. Un Reptile chassé et tué par un Insecte. Feuille jeun. Nat. (Cahiers Nat.): 87.

MUEHLBERGER, C. 1938. Über die Ernährung von *Troglophilus cavicola* Koll. Ent. Rundschau, 55: 81.

MULKERN, G. B., and J. F. ANDERSON. 1959. A technique for studying the food habits and preferences of grasshoppers. Jour. Econ. Ent., 52: 342.

MURTFELDT, M. E. 1889. The carnivorous habits of tree crickets. Insect Life, 2: 130–132.

NISHIDA, T. 1958. Extrafloral glandular secretions, a food source for certain insects. Proc. Hawaiian Ent. Soc., 16: 379–386.

PARKER, J. R. 1930. Some effects of temperature and moisture upon *Melanoplus mexicanus mexicanus* Saussure and *Camnula pellucida* Scudder. Bull. Montana Agric. Exp. Sta., 223: 132 pp.

PARROTT, P. J., and B. B. FULTON. 1914. Tree crickets injurious to orchard and garden fruits. Bull. N. York Agric. Exp. Sta., 388: 417–461.

PETTIT, R. H., and E. M. McDANIEL. 1918. Key to Orthoptera of Michigan with annotations. Spec. Bull. Michigan Agric. Exp. Sta., 83: 1–48.

PFADT, R. E. 1949. Food plants as factors in the ecology of the lesser migratory grasshopper, *Melanoplus mexicanus* (Saussure). Bull. Wyoming Agric. Exp. Sta., 290: iii + 48 pp.

———. 1949a. Food-plants, distribution, and abundance of the big-headed grasshopper, *Aulocara elliotti* (Thos.). Jour. Kansas Ent. Soc., 22: 69–74.

PHIPPS, C. R. 1930. Blueberry and huckleberry insects. Bull. Maine Agric. Exp. Sta., 356: 107–232.

POPENOE, C. H. 1922. Mushroom pests and how to control them. Farmers' Bull. U. S. Dept. Agric., 789: 3–13.

PUSSARD, R. 1926. A propos du régime alimentaire du Perce-Oreille *Forficula auricularia* L. Bull. Soc. Sci. nat. Rouen, 60–61: 171–177.

PUTNAM, L. G. 1947. Note on the disappearance of dead grasshoppers from sites of application of control measures. Canad. Ent., 79: 225–226.

RAMME, W. 1932. Die Vorderbeine carnivorer Laubheuschrecken als Fangorgane. Biol. Zentr., 52: 254–256.

RAU, P. 1915. The longevity and mating habits of *Dichromorpha viridis* Scud. Ent. News, 26: 27–28.

———. 1940. The life history of the American cockroach, *Periplaneta americana* Linn. Ent. News, 51: 121–124, 151–155, 186–189, 223–227, 273–278.

———. 1940a. The life history of the wood-roach, *Parcoblatta pennsylvanica* DeGeer. Ent. News, 51: 4–9, 33–35.

———. 1945. Food preferences of the cockroach, *Blatta orientalis* Linn. Ent. News, 56: 276–278.

———. 1947. Life history notes on the wood-roach, *Ischnoptera deropeltiformis* Brunner. Ent. News, 58: 1–4.

RAU, P., and N. RAU. 1913. The biology of *Stagmomantis carolina*. Trans. Acad. Sci. St. Louis, 22: 1–58.

REHN, J. A. G. 1923. North American Acrididae. Paper 3. A study of the Ligurotettigi. Trans. Amer. Ent. Soc., 44: 43–92.

———. 1944. On the significance of localized coloration in the creosote bush locust (*Bootettix*). Ent. News, 55: 158–164.

REHN, J. A. G., and H. J. GRANT, JR. 1960. A new concept involving the Subfamily Acridinae. Trans. Amer. Ent. Soc., 86: 173–185.

REHN, J. A. G., and M. HEBARD. 1909. An orthopterological reconnoissance of the southwestern United States. Part II. New Mexico and Western Texas. Proc. Acad. Nat. Sci. Philadelphia, 61: 111–175.

———, and ———. 1909a. An orthopterological reconnoissance of the southwestern United States. Part III. California and Nevada. Proc. Acad. Nat. Sci. Philadelphia, 61: 409–483.

———, and ———. 1914. A revision of the orthopterous group Insarae. Trans. Amer. Ent. Soc., 40: 37–184.

———, and ———. 1920. Descriptions of new genera and species of North American Decticinae. Trans. Amer. Ent. Soc., 46: 225–265.

REHN, J. A. G., and J. W. H. REHN. 1936. On new or redefined genera of Nearctic Melanopli. Trans. Amer. Ent. Soc., 62: 1–30.

REHN, J. A. G., and J. W. H. REHN. 1938. The post-oak locust (*Dendrotettix quercus*) in the eastern United States, with notes on macropterism in the species. Trans. Amer. Ent. Soc., 64: 79–95.

RÉMY, P. 1931. Observations sur les moeurs de quelques Orthoptères cavernicoles. Ann. Sci. Nat. (Zool.), Paris, (10) 14: 262–273.

RICHARDS, A. M. 1954. Notes on food and cannibalism in *Macropathus filifer* Walker (Rhaphidophorinae), 1869. Trans. Roy. Soc. N. Zealand, 82: 733–737.

RICHARDS, O. W., and N. WALOFF. 1954. Studies on the biology and population dynamics of British grasshoppers. Anti-Locust Bull. Anti-Locust Res. Centre, 17: 1–182.

RICHARDS, T. J. 1952. *Nemobius sylvestris* in S. E. Devon. The Ent., 85: 83–87, 108–111, 136–141, 161–166.

RILEY, C. V. 1878. The Rocky Mountain locust. Its habits and natural history. First Rept. U. S. Ent. Comm., 1877: 212–257.

————. 1889. Food habits of snowy tree-crickets. Insect Life, 2: 125.

RISBEC, J. 1935. Note sur les moeurs du *Chelisoches morio* Fabr. Bull. Soc. ent. Fr.: 31–32.

ROBERTS, R. A. 1937. Biology of the minor mantid, *Litaneutria minor* Scudder. Ann. Ent. Soc. Amer., 30: 111–121.

ROEDER, K. D. 1936. Raising the praying mantis for experimental purposes. Science, 83: 582–583.

ROLLINAT, R. 1926. Quelques observations sur la Mante religieuse, principalement sur la nourriture pendant le premier âge. Rev. Hist. nat. appl., 7: 242–251, 270–276.

ROONWAL, M. L. 1953. Food-preference experiments on the desert locust, *Schistocerca gregaria* (Forskal), in its permanent breeding grounds in Mekran. Jour. Zool. Soc. India, 5: 44–58.

ROTH, H. L. 1917. Observations on the growth and habits of the stick insect, *Carausius morosus* Br.; intended as a contribution towards a knowledge of variation in an organism which reproduces itself by the parthenogenetic method. Trans. Roy. Ent. Soc. London, 1916: 345–386.

ROTH, L. M., and E. R. WILLIS. 1957. The medical and veterinary importance of cockroaches. Misc. Coll. Smithsonian Inst. Washington, 134: 1–137.

RUBTSOV, I. A. 1932. The habitats and conditions of grasshopper outbreaks in East Siberia. Bull. Plant Protection (U.S.S.R.), Ser. I, Ent., 3: 33–130.*

RUMMEL, C. 1926. Observations on polygamous and supposedly cannibalistic insects of the Order Orthoptera. Bull. Brooklyn Ent. Soc., 21: 144.

ST. QUINTIN, W. H. 1907. Leaf-insects in captivity. The Ent., 40: 73–75. 163.

SARGENT, H. J. 1937. Feeding habits of stick insects. Nature, 139: 156–157.

SAVIN, M. B. 1927. Food preferences of the black cricket (*Gryllus assimilis*) with special reference to the damage done to fabrics. Ent. News, 38: 4–10, 33–39.

SCHARFF, D. K. 1954. The role of food plants and weather in the ecology of *Melanoplus mexicanus mexicanus* (Saussure). Jour. Econ. Ent., 47: 485–489.

SCHWABE, C. W. 1949. Observations on the life history of *Pycnoscelus surinamensis* (Linn.), the intermediate host of the chicken eyeworm in Hawaii. Proc. Hawaiian Ent. Soc., 13: 433–436.

SCUDDER, S. H. 1900. A tropical type of acridian new to the United States. Jour. N. York Ent. Soc., 8: 213–214.

SERGENT, E., and A. PONCET. 1951. L'effect répulsif du feuillage du Mélia, puissant sur certaines espèces d'acridiens, est nul sur d'autres espèces très voisines. Arch. Inst. Pasteur Algéri, 29: 305–307.

SEVERIN, H. C. 1926. The common black field cricket (*Gryllus assimilis* Fab.) and its control. Jour. Econ. Ent., 19: 218–227.

SEVERIN, H. H. P., and H. C. SEVERIN. 1911. The life-history of the walking-stick, *Diapheromera femorata* Say. Jour. Econ. Ent., 4: 307–320.

SHOTWELL, R. L. 1930. A study of the lesser migratory grasshopper. Tech. Bull. U. S. Dept. Agric., 190: 1–34.

————. 1941. Life histories and habits of some grasshoppers of economic importance on the great plains. Tech. Bull. U. S. Dept. Agric., 774: 47 pp.

SINGH, B. 1952. Observation on the biology of the cricket, *Gymnogryllus humeralis* Walker, in the Dehra Dun Insectary. Jour. Zool. Soc. India, 4: 47–61.

SKINNER, H. 1905. Destructiveness of the Australian roach *Periplaneta australasiae*. Ent. News, 16: 183.

SLADDEN, D. E., and H. R. HEWER. 1938. Transference of induced food-habit from parent to offspring, III. Proc. Royal Soc. London (B), 126: 30–44.

SMITH, J. B. 1892. Grasshoppers, locusts, and crickets. Bull. N. Jersey Agric. Exp. Sta., 90: 1–34.

SMITH, R. C. 1920. Predacious grasshoppers. Jour. Econ. Ent., 13: 491.

SNODGRASS, R. E. 1905. The coulee cricket of central Washington (*Peranabrus scabricollis* Thomas). Jour. N. York Ent. Soc., 13: 74–82.

SOMES, M. P. 1914. The Acridiidae of Minnesota. Bull. Minnesota Agric. Exp. Sta., 141: 100 pp.

STROHECKER, H. F. 1952. Descriptions of new species and notes on North American Orthoptera. Amer. Midl. Nat., 48: 683–688.

STEINHAUS, E. A. 1946. Insect microbiology. Comstock Publ. Co., Ithaca, N. York: x + 763 pp.

————. 1952. Infectious diseases of insects. In: Insects. The Yearbook of Agriculture. U. S. Gov. Print. Off., Washington, D. C.: 388–394.

STRENGER, A. 1950. Ein Beitrag zur Biologie von *Forficula auricularia*. Oesterreichische Zool. Zeit., 2: 624–638.

SVIRIDENKO, P. A. 1924. Biological observations on the Moroccan locust. Sev. Obl. Stants. Zasch. Rast. Vredit, Petrograd: 64 pp.*

SWAIN, R. B. 1940. The Mormon cricket and range vegetation. Univ. Colorado Studies (A), 26: 117–120.

SWEETMAN, H. L. 1936. The biological control of insects. Comstock Publ. Co., Ithaca, N. York: xii + 461 pp.

SWEZEY, O. H. 1905. Leaf-hoppers and their natural enemies, Pt. vii. Rept. Agric. Exp. Sta. Hawaii, i (pt. 7): 211–238.

TEALE, E. W. 1944. Unusual fare of praying mantis. Bull. Brooklyn Ent. Soc., 39: 34.

TEPPER, J. G. O. 1900. Notes on cockroaches in South Australia. Bull. U. S. Dept. Agric. Div. Ent., 22 (N. S.): 95–96.

TERRY, F. W. 1905. Leaf-hoppers and their natural enemies, Pt. V. Bull. Exp. Sta. Hawaiian Sugar Planters' Assoc., 1 (pt. V): 163–181.

TEYROVSKÝ, V. 1951. The prey and the hunting and feeding manners of *Decticus verrucivorus* (L.). Přírod. Sborn. Ostrav. Kraje, Opava, 12: 114–126.

THIAGARAJAN, K. B. 1939. The habits of the common earwig of Annamalainagar, *Euborellia stali* (Dohrn). Jour. Bombay Nat. Hist. Soc., 40: 721–723.

THIEROLF, W. R. 1928. The economic importance of *Paratenodera sinensis*. Ent. News, 39: 112–116, 140–145.

THOMAS, C. A. 1939. The animals associated with edible fungi. Jour. N. York Ent. Soc., 47: 11–37.

THOMAS, W. A. 1928. The Porto Rican mole cricket. Farmers' Bull. U. S. Dept. Agric., 1561: 1–8.

THOMSON, A. 1882. Notes on a species of stick insect reared in the insect-house in the Society's Gardens. Proc. Roy. Zool. Soc. London: 718–719.

TINKHAM, E. R. 1944. Biological, taxonomic and faunistic studies on the shield-back katydids of the North American deserts. Amer. Midl. Nat., 31: 257–328.

TOWNSEND, C. H. T. 1893. Note on *Ceuthophilus* eating lace curtains and other fabrics. Insect Life, 6: 58.

TURNER, C. L. 1915. Breeding habits of *Ceuthophilus latens,* the camel cricket. Bull. Wisconsin Nat. Hist. Soc., 13: 32–40.

UNITED STATES DEPARTMENT OF AGRICULTURE. 1938. Soils of the United States. In: Soils and men. Yearbook Soil Surv. Div. Bur. Chem. Soils: 1019–1161.

URQUHART, F. A. 1938. The oviposition and cannibalistic habits of the narrow-winged katydid (*Phaneroptera pistillata* Brunner). Canad. Field-Nat., 52: 51–53.

————. 1941. An ecological study of the Saltatoria of Point Pelee, Ontario. Biol. Series Univ. Toronto Studies, 50: 91 pp.

UVAROV, B. P. 1921. *Eremiaphila fraseri, sp. n.,* a new mantid from Mesopotamia. Ent. Mon. Mag., 57: 175–176.

————. 1928. Locusts and grasshoppers. A handbook for their study and control. Imp. Bur. Ent., London: 1–352.

————. 1931. Insects and climate. Trans. Roy. Ent. Soc. London, 79: 1–186.

VALOVA, A. V. 1924. Feeding habits of *Stenobothrus morio,* Fab., and of other boreal grasshoppers. Izv. Sibirsk. Sta. Zasch. Rast., 1(4): 16–35.*

VAN DER MERWE, C. P., and C. C. KENT. 1925. The elegant grasshopper (*Zonocerus elegans,* Thunb.). Reprint Jour. Union S. Africa Dept. Agric., 2: 3–16.

VAN ZWALUWENBURG, R. H. 1918. The changa or West Indian mole cricket. Bull. Porto Rico Agric. Exp. Sta., 23: 28 pp.

VERDCOURT, B. 1947. A note on the food of *Acrydium* Geoff. Ent. Mon. Mag., 83: 190.

VILLAMOR, I. 1914. Locust vs. agriculture. Bur. Print. Philippines, Manila: 1–46.

VOLKONSKY, M. 1937. Sur l'action acridifuge des extraits de feuilles de *Melia azedarach.* Arch. Inst. Pasteur Algéri, 15: 427–432. Translation in Agric. Live-Stock India, 9: 286–289 (1939).

VOUKASSOVITCH, P. 1924. Sur le régime alimentaire des Forficules. Feuille Nat. (Cahiers Nat.), 45: 101–102.

VUILLAUME, M. 1953. Chimiotropisme, préférences alimentaires de *Zonocerus variegatus* L. Rev. Path. vég., 32: 161–170.

WALKER, E. M. 1937. *Grylloblatta,* a living fossil. Trans. Royal Soc. Can., 31: 1–10.

WALLACE, H. S. 1955. Revision of the genus *Aeoloplides.* Ann. Ent. Soc. Amer., 48: 453–480.

WATSON, J. R. 1941. Migrations and food preferences of the lubberly locust. Florida Ent., 24: 40–42.

WEISS, H. B., and E. L. DICKERSON. 1918. The European mole cricket, *Gryllotalpa gryllotalpa,* Linn., an introduced insect pest. Jour. N. York Ent. Soc., 26: 18–23.

WHEELER, W. M. 1900. The habits of *Myrmecophila nebrascensis* Bruner. Psyche, 9: 111–115.

WHEETING, L. C., and A. BAUER. 1930. Soil survey of Washtenaw Co., Michigan. U. S. Dept. Agric. Bur. Chem. Soils, series 1930, 21: 1–47.

WHEETING, L. C., and S. G. BERQUIST. 1928. Soil survey of Livingston Co., Michigan. U. S. Dept. Agric. Bur. Chem. Soils, series 1923, 37: 1203–1222.

WILLIAMS, C. B., and B. A. BUXTON. 1916. On the biology of *Sphodromantis guttata* (Mantidae). Trans. Roy. Ent. Soc. London: 86–100.

WILLIAMS, C. E. 1904. Notes on the life history of *Gongylus gongyloides,* a mantis of the tribe Empusides and a floral simulator. Trans. Roy. Ent. Soc. London: 125–137.

WILLIAMS, J. B. 1907. Practical and popular entomology, no. 22. The walking-stick insect (*Diapheromera femorata*). Canad. Ent., 39: 261–263.

WILLIAMS, L. H. 1954. The feeding habits and food preferences of Acrididae and the factors which determine them. Trans. Roy. Ent. Soc. London, 105: 423–454.

WOLCOTT, G. N. 1923. Insectae Portoricensis. Jour. Dept. Agric. Porto Rico, 7: 313 pp.

WÜNN, H. 1909. Beobachtungen über eine in Mitteleuropaeingeschleppte Höhlenheuschrecke. Zeit. wiss. Insektenbiol., 5: 82–87, 113–120, 163–166.

WYMBS, M. 1939. Mantis and mouse (excerpt from letter). Jour. N. York Ent. Soc., 47: 314.

ZAPPE, M. P. 1918. A cockroach pest of greenhouses. *Pycnoscelus* (*Leucophaea*) *surinamensis* Linn. Bull. Connecticut Agric. Exp. Sta., 203: 302–313.

TABLE I[17]
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Parcoblatta uhleriana	1	F	Rodent feces		9:30 P.M.	Aug. 10, '55	31	SKG
" "	1	F	Crataegus sp.	Fruit	10:20 P.M.	Aug. 15, '55	31	SKG
Diapheromera femorata	1	F	Tilia americana	Leaf	11:30 P.M.	Aug. 28, '54	8	SKG
" "	1	F	Rubus occidentalis	Leaf	10:45 P.M.	Sept. 29, '54	8	SKG
" "	1	F	Prunus serotina	Leaf	10:30 P.M.	Aug. 9, '55	31	SKG
" "	1	Nymph	Corylus americana	Leaf	9:45 P.M.	July 1, '58	27	SKG
" "	1	Nymph	Quercus velutina	Leaf	10:45 P.M.	July 9, '59	27	SKG
" "	1	M	Quercus rubra	Leaf	9:45 P.M.	July 30, '59	27	SKG
" "	1	?	Lespedeza capitata*	Flower	12:35 P.M.	Aug. 4, '59	27	JKH
" "	1	Nymph	Quercus velutina	Leaf	11:20 P.M.	Aug. 5, '59	27	JKH
" "	1	Nymph	Quercus velutina	Leaf	10:00 P.M.	Aug. 17, '59	27	JKH
Chloealtis conspersa	1	F	Fragaria virginiana	Leaflet (dry)	11:30 A.M.	July 14, '54	13	SKG
" "	2	FF	Danthonia spicata	Leaf (dry)	11:30 A.M.	July 14, '54	13	SKG
" "	1	?	Poa pratensis	Leaf	4:00 P.M.	July 14, '59	27	JKH
Chorthippus longicornis	1	?	Andropogon Gerardi	Leaf	12:10 P.M.	Sept. 1, '53	14	SKG
Orphulella speciosa	1	M	Poa pratensis	Leaf	9:30 A.M.	July 14, '54	12	SKG
Pseudopomala brachyptera	1	Nymph	Agrostis alba	Leaf	11:30 A.M.	July 27, '57	31B	SKG
Syrbula admirabilis	1	Nymph	Aristida purpurascens	Leaf	1:00 P.M.	June 26, '58	27	SKG
Arphia p. pseudonietana	1	F	Poa pratensis	Leaf	4:05 P.M.	Aug. 5, '59	27	JKH
Camnula pellucida	1	F	Poa pratensis	Leaf	11:00 A.M.	July 18, '55	31B	SKG
Chortophaga viridifasciata	1	F	Mentha piperita	Leaf & petiole	3:00 P.M.	May 17, '54	22B	SKG
" "	Same indiv.		Dactylis glomerata	Leaf	3:00 P.M.	May 17, '54	22B	SKG
" "	1	?	Danthonia spicata*	Leaf	11:30 A.M.	May 25, '54	17A	SKG
" "	1	?	Dactylis glomerata	Leaf	9:30 A.M.	June 9, '54	17A	SKG
Dissosteira carolina	1	M	Poa pratensis	Leaf	11:00 A.M.	July 25, '54	12	SKG
" "	1	?	Cirsium arvense	Leaf	1:30 P.M.	Aug. 5, '54	28C	SKG
" "	1	?	Berteroa incana*	Leaf	2:15 P.M.	July 23, '59	27	JKH
" "	1	F	Moss	Leaf	3:30 P.M.	Aug. 11, '59	27	JKH
Encoptolophus s. sordidus	1	F	Poa pratensis	Leaf	3:15 P.M.	Sept. 3, '55	31B	SKG
Spharagemon b. bolli	1	F	Hieracium longipilum	Leaf (dry)	10:00 A.M.	July 16, '59	27	JKH
" " "	1	F	Poa compressa	Leaf (dry)	4:45 P.M.	July 28, '59	27	JKH
" " "	1	M	Moss	Leaf	12:15 M.	Aug. 2, '59	27	JKH
" " "	1	F	Equisetum arvense	Leaf	3:00 P.M.	Aug. 8, '59	27	JKH
Spharagemon collare	1	F	Rumex Acetosella	Leaf (basal)	11:10 A.M.	Sept. 3, '55	31B	SKG
" "	1	M	Poa pratensis	Leaf	12:45 P.M.	Sept. 3, '55	31B	SKG
" "	1	M	Composite sp.	Stem (broken tip)	3:00 P.M.	Sept. 3, '55	31B	SKG

*Nibbled

[17] See p.163 for a discussion of the formulation and use of the following data.

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Spharagemon collare	1	F	Poa pratensis	Spikelet	10:07 P.M.	July 17, '59	27	JKH
" "	1	F	Penstemon hirsutus	Leaf	5:00 P.M.	July 23, '59	27	JKH
" "	1	M	Lactuca canadensis	Flower head	1:45 P.M.	July 29, '59	27	JKH
Melanoplus b. bilituratus	1	M	Poa pratensis	Leaf	10:30 A.M.	Sept. 3, '55	31B	SKG
" " "	1	M	Solidago nemoralis	Flower head	11:45 A.M.	Sept. 3, '55	31B	SKG
" " "	1	F	Rumex Acetosella	Leaf (basal)	12:45 P.M.	Sept. 3, '55	31B	SKG
" " "	1	?	Moss	Leaf	1:55 P.M.	July 25, '59	27	JKH
" " "	1	?	Rudbeckia serotina	Leaf	2:25 P.M.	July 25, '59	27	JKH
Melanoplus bivittatus	1	F	Mentha arvensis	Leaf	9:30 A.M.	Aug. 31, '53	5	SKG
" "	1	F	Verbena urticifolia	Leaf	11:00 A.M.	Sept. 1, '53	14	SKG
" "	2	FF	Solidago canadensis	Ray flower	11:00 A.M.	Sept. 1, '53	14	SKG
" "	1	Nymph	Solidago canadensis	Ray flower	11:00 A.M.	Sept. 1, '53	14	SKG
" "	1	F	Scirpus atrovirens	Leaf	10:30 P.M.	Sept. 3, '53	5	SKG
" "	Same indiv.		Typha latifolia	Leaf	10:30 P.M.	Sept. 3, '53	5	SKG
" "	2	M,F	Aster puniceus	Flower head	10:15 A.M.	Sept. 16, '53	18	SKG
" "	1	?	Sagittaria latifolia	Leaf	10:00 P.M.	Aug. 2, '54	5	SKG
" "	1	Nymph	Potentilla fruticosa	Leaf & terminal bud	8:45 P.M.	Aug. 13, '53	28D	SKG
" "	1	F	Typha latifolia	Leaf	8:45 P.M.	Aug. 13, '53	28D	SKG
" "	2	?	Phleum pratense	Spikelet	12:30 P.M.	July 2, '58	27	AMW
" "	1	?	Daucus Carota	Leaf	11:40 A.M.	July 14, '59	27	JKH
" "	1	M	Erechtites hieracifolia	Leaf	4:10 P.M.	July 14, '59	27	JKH
" "	1	?	Asclepias syriaca	Flower	7:10 P.M.	July 16, '59	27	JKH
" "	1	F	Asparagus officinalis	Stem	10:35 P.M.	Aug. 12, '59	27	JKH
Melanoplus confusus	2	M,F	Cirsium arvense	Leaf	11:00 A.M.	July 1, '55	31B	SKG
" "	1	M	Monarda fistulosa	Perianth	10:00 A.M.	July 26, '55	31B	SKG
" "	1	M	Asclepias syriaca	Leaf	11:30 A.M.	June 18, '57	31	SKG
" "	1	F	Phleum pratense	Leaf	11:45 A.M.	June 18, '57	31	SKG
" "	1	M	Rumex Acetosella*	Leaf (basal)	12:30 M.	June 19, '57	13	SKG
" "	Same indiv.		Solidago prob. juncea	Leaf (basal)	12:30 M.	June 19, '57	13	SKG
" "	1	M	Cirsium arvense	Leaf	10:20 A.M.	July 5, '57	31B	SKG
" "	1	F	Carya glabra	Leaf (dried)	9:30 A.M.	June 18, '58	27	SKG
" "	1	F	Acheta pennsylvanicus	Body (dried)	12:15 M.	June 19, '58	27	SKG
" "	1	F	Setaria glauca	Leaf	4:00 P.M.	July 20, '59	27	JKH
" "	1	?	Poa pratensis	Leaf (dried)	4:00 P.M.	July 29, '59	27	JKH

*Nibbled

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Melanoplus f.-r. f.-r.	1	F	Cichorium Intybus	Flower head	11:00 A.M.	Aug. 31, '53	6	SKG
" " "	Same indiv.		Ambrosia artemisiifol.	Flower head	11:00 A.M.	Aug. 31, '53	6	SKG
" " "	1	F	Trifolium sp.	Leaflet	11:00 A.M.	Aug. 31, '53	6	SKG
" " "	1	?	Typha latifolia	Leaf	10:30 P.M.	Sept. 3, '53	5	SKG
" " "	1	M	Plantago Rugelii*	Leaf	10:30 P.M.	July 19, '54	12	SKG
" " "	1	Nymph	Solidago canadensis	Leaf (dry)	11:30 A.M.	Aug. 9, '54	21A	SKG
" " "	1	?	Dactylis glomerata	Leaf	2:30 P.M.	Aug. 25, '54	12	SKG
" " "	1	?	Trifolium pratense	Leaflet	2:30 P.M.	Aug. 25, '54	12	SKG
" " "	1	Nymph	Dactylis glomerata	Leaf	2:30 P.M.	Aug. 25, '54	12	SKG
" " "	1	?	Aster lateriflorus	Flower bud	11:45 P.M.	Aug. 28, '54	13	SKG
" " "	1	?	Solidago graminifolia	Flower head	10:00 P.M.	Sept. 3, '54	25	SKG
" " "	1	?	Scirpus validus	Spike	10:00 P.M.	Sept. 3, '54	25	SKG
" " "	1	?	Aster lateriflorus	Leaf	10:00 P.M.	Sept. 3, '54	25	SKG
" " "	1	Nymph	Cirsium arvense	Leaf	11:00 A.M.	July 26, '55	31B	SKG
" " "	1	Nymph	Monarda fistulosa	Perianth	3:30 P.M.	July 29, '55	31B	SKG
" " "	1	Nymph	Monarda fistulosa	Leaf	10:28 P.M.	July 30, '59	27	SKG
" " "	1	Nymph	Monarda fistulosa	Leaf	10:35 P.M.	July 30, '59	27	SKG
" " "	1	Nymph	Desmodium paniculatum	Flower	10:45 P.M.	July 30, '59	27	SKG
" " "	1	Nymph	Solidago juncea	Flower head	11:10 P.M.	July 31, '59	27	JKH
" " "	1	M	Asclepias syriaca	Leaf	10:30 P.M.	Aug. 11, '59	27	JKH
" " "	1	F	Asclepias syriaca	Leaf	10:25 P.M.	Aug. 12, '59	27	JKH
" " "	1	M	Monarda fistulosa	Leaf	12:00 P.M.	Aug. 12, '59	27	JKH
" " "	1	F	Berteroa incana	Fruit	10:15 P.M.	Aug. 13, '59	27	JKH
" " "	1	M	Verbascum Thapsus	Flower (unopened)	10:25 P.M.	Aug. 13, '59	27	JKH
" " "	1	M	Asclepias syriaca	Flower (dry)	11:45 P.M.	Aug. 14, '59	27	JKH
" " "	1	M	Asclepias syriaca	Fruit	11:45 P.M.	Aug. 15, '59	27	JKH
" " "	1	F	Monarda fistulosa	Leaf	10:20 P.M.	Aug. 22, '59	27	JKH
Melanoplus f.-r. f.-r. (?)	1	Nymph	Phleum pratense	Spikelet & leaf	11:00 P.M.	July 1, '55	31B	SKG
Melanoplus keeleri luridus	1	F	Solidago canadensis	Leaf	10:00 A.M.	Aug. 3, '55	14	SKG
" " "	1	M	Solidago juncea	Leaf	3:45 P.M.	Nov. 14, '58	28	SKG
" " "	1	?	Erigeron strigosus	Leaf	4:20 P.M.	July 23, '59	27	JKH
" " "	1	?	Monarda fistulosa	Leaf	4:10 P.M.	July 27, '59	27	JKH
" " "	1	?	Monarda fistulosa	Leaf	4:40 P.M.	July 27, '59	27	JKH

*Nibbled

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Melanoplus s. scudderi	1	F	Melilotus alba	Flower & stalk	9:30 A.M.	Sept. 3, '53	15	SKG
" " "	1	?	Plantago sp.*	Leaf	2:30 P.M.	Sept. 1, '54	13	SKG
Melanoplus sp.	1	Nymph	Phleum pratense	Leaf	10:00 A.M.	July 19, '57	31B	SKG
" "	1	Nymph	Monarda fistulosa	Leaf	10:30 A.M.	July 19, '57	31B	SKG
" "	1	Nymph	Cirsium arvense	Leaf	10:40 A.M.	July 27, '57	31B	SKG
" "	1	Nymph	Phleum pratense	Leaf	10:42 A.M.	July 27, '57	31B	SKG
" "	1	Nymph	Melanoplus b. bilituratus (dead)	Gular region	1:00 P.M.	July 27, '57	28B	SKG
" "	1	Nymph	Verbascum Thapsus	Flower	10:30 P.M.	July 17, '59	27	JKH
" "	1	Nymph	Poa compressa	Spikelet	10:31 P.M.	July 17, '59	27	JKH
" "	3	Nymphs	Berteroa incana	Fruit	10:35 P.M.	July 17, '59	27	JKH
" "	1	Nymph	Rudbeckia serotina	Flower head	10:45 P.M.	July 17, '59	27	JKH
" "	1	Nymph	Achillea Millefolium	Leaf	3:15 P.M.	July 29, '59	27	JKH
" "	1	M	Melanoplus sp. F	Wings (while F struggled)	4:50 P.M.	Aug. 5, '59	27	JKH
" "	3	Nymphs	Monarda fistulosa	Leaf & flower	12:15 P.M.	Aug. 12, '59	27	JKH
" "	2	Nymphs	Desmodium paniculatum	Leaf & flower	12:20 P.M.	Aug. 12, '59	27	JKH
" "	1	F	Cirsium vulgare	Flower head	10:20 P.M.	Aug. 17, '59	27	JKH
Schistocerca lineata	1	F	Rumex Acetosella*	Leaf (basal)	3:00 P.M.	Oct. 6, '54	27	SKG
" "	1	Nymph	Lespedeza capitata	Leaflet	11:00 P.M.	Aug. 9, '55	31B	SKG
" "	1	Nymph	Equisetum arvense	Leaf	3:05 P.M.	July 25, '59	27	JKH
" "	1	Nymph	Lespedeza hirta	Perianth	11:30 P.M.	July 28, '59	27	JKH
" "	1	F	Poa pratensis	Leaf (dry)	3:15 P.M.	Aug. 12, '59	27	JKH
" "	Same indiv.		Erigeron strigosus	Leaf (dry)	3:25 P.M.	Aug. 12, '59	27	JKH
" "	1	F	Desmodium paniculatum	Leaflet	11:10 P.M.	Aug. 16, '59	27	JKH
" "	1	F	Moss	Leaf	3:05 P.M.	Aug. 18, '59	27	JKH
" "	1	F	Rubus sp.	Leaflet	11:45 P.M.	Aug. 20, '59	27	JKH
Ceuthophilus brevipes	1	F	Lumbricus terrestris	Body (dry)	9:30 P.M.	Sept. 21, '55	36	DCE
Ceuthophilus pallidipes	1	?	Bracket fungus	Fruiting body	10:30 P.M.	Sept. 20, '55	37	DCE
" "	1	?	Leaf mold	Hyphae	10:30 P.M.	Sept. 20, '55	37	DCE
Ceuthophilus thomasi	1	F	Tsuga canadensis	Cone (green)	11:30 P.M.	Aug. 27, '55	38	DCE
Ceuthophilus uhleri	2	M,F	Magicicada sp.	Body	8:45 P.M.	Aug. 26, '55	39	DCE
Amblycorypha oblongifolia	1	F	Solidago canadensis	Leaf	11:00 P.M.	Aug. 18, '54	8	SKG
" "	1	?	Impatiens capensis	Leaf	11:00 P.M.	Aug. 28, '54	8	SKG
" "	1	?	Solidago canadensis	Leaf	11:00 P.M.	Aug. 28, '54	8	SKG
" "	1	?	Solidago canadensis	Flower head	9:45 P.M.	Sept. 8, '54	8	SKG
" "	1	?	Solidago canadensis	Leaf	9:45 P.M.	Sept. 8, '54	8	SKG

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Amblycorypha oblongifolia	1	?	Vitis riparia	Leaf	9:45 P.M.	Sept. 8, '54	8	SKG
" "	1	?	Monarda fistulosa	Leaf	9:45 P.M.	Sept. 8, '54	8	SKG
" "	1	?	Rubus occidentalis	Leaf	9:45 P.M.	Sept. 8, '54	8	SKG
" "	1	M	Solidago canadensis	Flower head	11:00 P.M.	Sept. 19, '54	8	SKG
" "	1	?	Solidago canadensis	Flower head	10:00 P.M.	Aug. 11, '55	8	SKG
Amblycorypha rotundifolia	1	M	Collinsonia canaden.	Leaf	10:00 P.M.	Aug. 28, '53	11	SKG
" "	Same indiv.		Collinsonia canaden.	Flower & stalk	10:00 P.M.	Aug. 28, '53	11	SKG
" "	1	?	Solidago canadensis	Leaf	11:00 P.M.	Aug. 28, '54	8	SKG
" "	1	Nymph	Rubus flagellaris	Leaf (dry)	9:40 P.M.	June 18, '58	27	AMW
Scudderia c. curvicauda	1	F	Typha latifolia	Leaf	10:00 P.M.	Aug. 2, '54	5	SKG
" " "	1	?	Asparagus officinalis	Leaf	11:30 P.M.	Aug. 28, '54	13	SKG
" " "	1	Nymph	Carya glabra	Gall on leaf	12:30 M.	June 24, '55	27	SKG
" " "	1	Nymph	Asclepias syriaca	Leaf (dry)	11:00 A.M.	July 1, '55	31B	SKG
" " "	1	F	Typha latifolia	Leaf	10:45 P.M.	Aug. 12, '55	28D	SKG
" " "	1	F	Impatiens capensis	Flower (unopened)	10:45 P.M.	Aug. 12, '55	28D	SKG
" " "	2	FF	Apocynum androsaem.	Flower & stalk	9:50 P.M.	June 30, '59	27	SKG
" " "	1	Nymph	Rubus sp.	Leaf	12:30 P.M.	July 10, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca	Flower (unopened)	12:35 P.M.	July 10, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca	Flower bud	11:50 A.M.	July 14, '59	27	JKH
" " "	1	F	Carex tribuloides	Leaf (dry)	12:00 M.	July 14, '59	27	JKH
" " "	1	?	Asclepias syriaca	Leaf	4:15 P.M.	July 16, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca	Leaf	12:30 P.M.	July 17, '59	27	SKG
" " "	1	F	Verbascum Thapsus	Flower	10:23 P.M.	July 30, '59	27	SKG
" " "	1	F	Asclepias tuberosa	Leaf	11:30 P.M.	Aug. 14, '59	27	JKH
" " "	1	?	Asclepias syriaca	Leaf	12:20 P.M.	Aug. 20, '59	27	JKH
Scudderia f. furcata	1	?	Aster sagittifolius	Flower head	4:00 P.M.	Sept. 10, '53	17A	SKG
" " "	1	F	Rhamnus alnifolia	Leaf	9:30 P.M.	Aug. 9, '54	13	SKG
" " "	1	Nymph	Betula pumila	Leaf (dry)	3:00 P.M.	Aug. 12, '54	28D	SKG
" " "	1	?	Aster sagittifolius	Flower head	11:30 P.M.	Aug. 28, '54	13	SKG
" " "	1	Nymph	Monarda fistulosa	Perianth	9:30 A.M.	July 18, '55	31	SKG
" " "	1	F	Impatiens capensis	Flower	8:30 P.M.	Aug. 13, '55	28D	SKG
" " "	1	F	Impatiens capensis	Fruit	9:00 P.M.	Aug. 13, '55	28D	SKG
" " "	1	M	Polymnia canadensis	Leaf	8:30 P.M.	Aug. 13, '55	35	DCE
" " "	1	M	Rhus typhina	Leaflet	10:30 P.M.	Aug. 23, '55	8	SKG
" " "	1	Nymph	Asclepias syriaca	Flower (dry)	11:50 P.M.	July 16, '59	27	SKG
" " "	1	Nymph	Asclepias syriaca	Leaf (dry)	11:30 P.M.	July 24, '59	27	SKG
" " "	1	Nymph	Asclepias syriaca	Leaf (dry)	10:50 P.M.	July 28, '59	27	JKH

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Scudderia f. furcata	1	Nymph	Asclepias syriaca	Flower	10:10 P.M.	July 30, '59	27	SKG
Scudderia texensis	1	M	Verbascum Thapsus	Flower	10:55 P.M.	July 17, '59	27	JKH
" "	1	F	Cornus racemosa	Leaf	11:30 A.M.	July 27, '59	27	JKH
Scudderia sp.	1	?	Verbascum Thapsus	Flower	10:50 P.M.	Aug. 12, '59	27	JKH
" "	1	Nymph	Rubus sp.	Leaf	12:30 P.M.	Aug. 17, '59	27	JKH
Neoconocephalus ensiger	1	F	Andropogon Gerardi	Grain	11:30 P.M.	Sept. 11, '53	17B	SKG
" "	1	M	Agrostis alba	Grain (dry)	10:30 P.M.	Aug. 1, '54	13	SKG
" "	1	M	Plantago Rugelii	Fruit	11:30 P.M.	Aug. 28, '54	13	SKG
" "	2	MM	Setaria glauca	Grain	11:30 P.M.	Aug. 28, '54	13	SKG
" "	1	M	Rumex crispus	Fruit (dry)	10:30 P.M.	Sept. 3, '54	25	SKG
" "	1	F	Phleum pratense	Grain (dry)	1:00 A.M.	Aug. 10, '55	31B	SKG
" "	1	M	Setaria glauca	Grain	9:30 P.M.	Sept. 17, '58	13	SKG
Conocephalus attenuatus	20+	MM,FF	Eupatorium perfoliat.	Flower head	11:00 P.M.	Aug. 23, '54	29	SKG
" "	1	?	Scirpus atrovirens	Spike	11:00 P.M.	Aug. 23, '54	29	SKG
" "	1	?	Juncus effusus	Fruit	11:00 P.M.	Aug. 23, '54	29	SKG
" "	20+	MM,FF	Eupatorium perfoliat.	Flower head	9:30 P.M.	Sept. 1, '54	29	SKG
Conocephalus brevipennis	1	M	Leersia oryzoides	Leaf sheath	10:00 P.M.	Sept. 3, '53	5	SKG
" "	4	?	Leersia oryzoides	Spikelet	10:00 P.M.	Sept. 3, '53	5	SKG
" "	1	?	Leersia oryzoides	Leaf & sheath	10:00 P.M.	Sept. 3, '53	5	SKG
" "	1	?	Typha latifolia	Fruit	10:00 P.M.	Sept. 3, '53	5	SKG
" "	1	F	Aster laevis	Flower head	3:00 P.M.	Sept. 9, '53	4A	SKG
" "	1	Nymph	Sagittaria latifolia	Leaf	10:00 P.M.	Aug. 2, '54	5	SKG
" "	1	?	Agrostis alba	Spikelet	11:30 P.M.	Aug. 28, '54	13	SKG
" "	1	?	Setaria glauca	Spikelet	11:30 P.M.	Aug. 28, '54	13	SKG
" "	1	?	Panicum lanuginosum	Spikelet	11:30 P.M.	Aug. 28, '54	13	SKG
" "	2	?	Solidago canadensis	Flower head	10:00 P.M.	Sept. 3, '54	25	SKG
" "	2	?	Juncus tenuis	Fruit	10:00 P.M.	Sept. 3, '54	25	SKG
" "	2	?	Juncus Torreyi	Fruit	10:00 P.M.	Sept. 3, '54	25	SKG
" "	3	?	Scirpus atrovirens	Spike	10:00 P.M.	Sept. 3, '54	25	SKG
" "	1	?	Scirpus validus	Spike	10:00 P.M.	Sept. 3, '54	25	SKG
" "	4	?	Leersia oryzoides	Spikelet	10:00 P.M.	Sept. 3, '54	25	SKG
" "	1	?	Mimulus ringens	Flower	10:00 P.M.	Sept. 3, '54	25	SKG
" "	1	?	Vernonia altissima	Flower head	10:00 P.M.	Sept. 3, '54	25	SKG
" "	1	M	Muhlenbergia Schreberi	Spikelet	11:30 P.M.	Sept. 19, '54	8	SKG
" "	1	?	Chrysops sp.	Head & abdomen	10:30 A.M.	July 18, '55	31B	SKG
" "	1	M	Phleum pratense	Spikelet (dry)	1:00 A.M.	Aug. 10, '55	31B	SKG
" "	1	F	Impatiens capensis	Fruit	8:30 P.M.	Aug. 13, '55	28D	SKG

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Conocephalus brevipennis	1	Nymph	Andropogon Gerardi	Spikelet	1:30 A.M.	Aug. 14, '55	28D	SKG
" "	1	M	Impatiens capensis	Flower	2:00 A.M.	Aug. 14, '55	28D	SKG
Conocephalus brevipennis (?)	1	Nymph	Plantago lanceolata*	Perianth	11:00 A.M.	July 25, '54	12	SKG
" "	1	Nymph	Dipteran larva	Body (dry)	11:00 A.M.	July 25, '54	12	SKG
Conocephalus f. fasciatus	20+	MM,FF	Agrostis alba	Spikelet	10:30 P.M.	Aug. 2, '54	25	SKG
" " "	1	?	Impatiens capensis	Flower	11:00 P.M.	Aug. 23, '54	29	SKG
" " "	20+	MM,FF	Eupatorium perfoliat.	Flower head	11:00 P.M.	Aug. 23, '54	29	SKG
" " "	5	?	Eupatorium perfoliat.	Flower head	9:30 P.M.	Sept. 1, '54	29	SKG
" " "	1	F	Agrostis alba	Spikelet	10:30 P.M.	Sept. 3, '54	25	SKG
Conocephalus nigropleurum	1	M	Eupatorium perfoliat.	Flower head	10:15 A.M.	Sept. 16, '53	18	SKG
" "	1	F	Impatiens capensis	Flower	1:30 A.M.	Aug. 10, '55	28D	SKG
Conocephalus strictus	7	?	Setaria glauca	Spikelet	11:30 P.M.	Aug. 28, '54	13	SKG
" "	1	F	Phleum pratense	Spikelet (dry)	1:00 A.M.	Aug. 10, '55	31B	SKG
" "	2	M,F	Phleum pratense	Spikelet (dry)	10:30 P.M.	Aug. 10, '55	31B	SKG
" "	1	Nymph	Achillea Millefolium	Inflorescence	11:05 P.M.	July 17, '59	27	JKH
" "	1	?	Poa compressa	Spikelet (dry)	2:15 P.M.	July 28, '59	27	JKH
" "	Same indiv.		Rumex Acetosella	Flower (dry)	2:15 P.M.	July 28, '59	27	JKH
" "	1	Nymph	Verbascum Thapsus	Flower	11:15 P.M.	July 28, '59	27	JKH
" "	1	Nymph	Potentilla intermedia	Flower	11:20 P.M.	July 28, '59	27	JKH
" "	1	Nymph	Achillea Millefolium	Flower head	10:00 P.M.	July 30, '59	27	SKG
" "	1	Nymph	Mosquito	Entire body (taken in mid-air)	10:50 P.M.	July 30, '59	27	SKG
" "	1	Nymph	Rudbeckia serotina	Flower head	11:34 P.M.	July 30, '59	27	SKG
" "	1	F	Poa compressa	Spikelet	4:20 P.M.	Aug. 5, '59	27	JKH
" "	1	Nymph	Monarda fistulosa	Flower	10:25 P.M.	Aug. 5, '59	27	JKH
" "	1	Nymph	Ant	Entire body (while ant struggled)	3:20 P.M.	Aug. 8, '59	27	JKH
" "	1	M	Poa compressa	Spikelet	10:05 P.M.	Aug. 12, '59	27	JKH
" "	1	?	Asclepias syriaca	Leaf (dry)	11:40 P.M.	Aug. 14, '59	27	SKG
" "	1	Nymph	Undetermined insect	Entire body (captured in mid-air)	11:30 P.M.	Aug. 17, '59	27	JKH
" "	1	F	Moss	Leaf	3:00 P.M.	Aug. 18, '59	27	JKH
" "	1	F	Poa compressa	Spikelet	3:15 P.M.	Aug. 18, '59	27	JKH
" "	1	F	Poa compressa	Spikelet	9:35 P.M.	Aug. 19, '59	27	SKG
" "	1	F	Lespedeza capitata	Leaflet	9:15 P.M.	Aug. 22, '59	27	JKH
" "	1	Nymph	Achillea Millefolium	Flower head	9:40 P.M.	Aug. 22, '59	27	JKH
Conocephalus sp.	1	Nymph	Impatiens capensis	Flower	10:45 P.M.	Aug. 12, '55	28D	SKG
Orchelimum gladiator	1	M	Carex stricta var. strictior	Leaf	10:30 A.M.	July 8, '54	25	SKG
" "	1	M	Eleocharis calva	Spike	10:00 A.M.	July 15, '54	25	SKG

*Nibbled

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Orchelimum gladiator	1	M	Betula pumila	Fruit	3:00 P.M.	Aug. 19, '54	28D	SKG
Orchelimum nigripes	1	M	Typha latifolia	Fruit	10:30 P.M.	Sept. 3, '53	5	SKG
" "	2	FF	Typha latifolia	Fruit	10:30 P.M.	Sept. 3, '53	5	SKG
Orchelimum volantum	1	M	Carex comosa	Leaf (dry)	9:45 P.M.	Sept. 1, '54	29	SKG
Orchelimum vulgare	1	M	Carex vulpinoidea	Spike	1:15 A.M.	July 22, '59	27	JKH
Orchelimum sp.	1	?	Achillea Millefolium	Flower head	11:30 P.M.	Aug. 3, '59	27	JKH
" "	1	M	Poa compressa	Spikelet	12:05 P.M.	Aug. 17, '59	27	JKH
Acheta pennsylvanicus	1	F	Mucous		9:45 A.M.	Sept. 20, '57	40	SKG
" "	1	F	Melanoplus confusus	Leg	4:15 P.M.	June 18, '58	27	SKG
" "	1	?	Quercus sp.	Ament	3:45 P.M.	June 22, '58	8	SKG
" "	1	Nymph	Atlanticus testaceus	Abdomen (injured prey)	1:30 A.M.	July 12, '59	27	JKH
" "	1	M	Poa pratensis	Spikelet	10:45 P.M.	July 15, '59	27	JKH
Nemobius allardi	1	?	Daucus Carota*	Flower head	3:00 P.M.	Aug. 25, '54	12	SKG
Neoxabea bipunctata	2	FF	Polymnia canadensis	Flower head	8:30 P.M.	Aug. 13, '55	35	DCE
Oecanthus angustipennis	1	M	Polymnia canadensis	Flower head	8:30 P.M.	Aug. 13, '55	35	DCE
" "	1	?	Lactuca biennis	Flower head	10:00 P.M.	Sept. 5, '53	16	SKG
Oecanthus n. nigricornis	1	M	Monarda fistulosa	Flower (dry)	10:30 P.M.	Sept. 1, '53	10	SKG
" " "	1	M	Solidago canadensis	Flower head	10:30 P.M.	Sept. 1, '53	10	SKG
Oecanthus n. quadripunctatus	1	?	Solidago nemoralis	Flower head	10:00 P.M.	Sept. 5, '53	16	SKG
" " "	1	F	Aphids on Desmodium sessilifolium	Entire body	1:00 A.M.	Aug. 10, '55	31B	SKG
" " "	1	Nymph	Verbascum Thapsus	Flower	12:50 P.M.	July 8, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca	Flower bud	1:30 A.M.	July 10, '59	27	JKH
" " "	1	Nymph	Verbascum Thapsus	Flower	11:45 P.M.	July 15, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca	Fruit	12:15 P.M.	July 17, '59	27	SKG
" " "	1	Nymph	Verbascum Thapsus	Flower	11:15 P.M.	July 18, '59	27	JKH
" " "	1	Nymph	Verbascum Thapsus	Flower	11:10 P.M.	July 20, '59	27	JKH
" " "	1	Nymph	Verbascum Thapsus	Flower	11:30 P.M.	July 20, '59	27	JKH
" " "	1	Nymph	Monarda fistulosa*	Flower	12:00 P.M.	July 21, '59	27	JKH
" " "	1	Nymph	Asclepias syriaca*	Flower (dry)	12:45 P.M.	July 21, '59	27	JKH
" " "	1	M	Asclepias syriaca	Leaf	11:50 P.M.	July 24, '59	27	SKG
" " "	1	F	Monarda fistulosa*	Flower	11:00 P.M.	July 26, '59	27	JKH
" " "	Same indiv.		Monarda fistulosa	Flower	11:15 P.M.	July 26, '59	27	JKH
" " "	1	M	Asclepias syriaca	Leaf	11:30 P.M.	July 26, '59	27	JKH
" " "	1	Nymph	Verbascum Thapsus	Flower	11:10 P.M.	July 28, '59	27	JKH
" " "	1	Nymph	Solidago speciosa	Leaf (dry)	11:35 P.M.	July 28, '59	27	JKH
" " "	1	Nymph	Rubus flagellaris	Leaflet (dry)	9:35 P.M.	July 30, '59	27	SKG

*Nibbled

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

Feeder	No. of Feeders	Sex	Food	Part Eaten	Approx. Time	Date	Sta.	Observer
Oecanthus n. quadripunctatus	1	F	Achillea Millefolium	Flower head	10:18 P.M.	July 30, '59	27	SKG
" " "	1	Nymph	Desmodium paniculatum	Flower	10:47 P.M.	July 30, '59	27	SKG
" " "	1	F	Vernonia altissima	Flower head	11:00 P.M.	July 30, '59	27	SKG
" " "	2	?	Verbascum Thapsus	Flower	11:00 P.M.	July 31, '59	27	JKH
" " "	1	F	Desmodium paniculatum	Flower	11:45 P.M.	Aug. 3, '59	27	JKH
" " "	1	?	Vernonia sp.	Flower head	12:15 P.M.	Aug. 4, '59	27	JKH
" " "	2	M,F	Erigeron strigosus	Flower head	11:05 P.M.	Aug. 5, '59	27	JKH
" " "	1	Nymph	Lespedeza capitata	Flower	10:15 P.M.	Aug. 8, '59	27	JKH
" " "	1	M	Monarda fistulosa	Flower	10:35 P.M.	Aug. 8, '59	27	JKH
" " "	1	M	Asclepias syriaca	Leaf	10:50 P.M.	Aug. 8, '59	27	JKH
" " "	1	?	Erigeron canadensis	Fruit	10:45 P.M.	Aug. 11, '59	27	JKH
" " "	1	M	Asclepias syriaca	Leaf	9:55 P.M.	Aug. 12, '59	27	JKH
" " "	1	Nymph	Asparagus officinalis	Stem (bark)	10:40 P.M.	Aug. 16, '59	27	JKH
Oecanthus niveus	2	Nymphs	Lychnis alba	Petal	11:00 P.M.	July 28, '54	8	SKG
" "	1	F	Lonicera tatarica	Leaf (dry)	10:30 P.M.	Aug. 9, '54	13	SKG
Anaxipha exigua	1	F	Polymnia canadensis	Flower head	8:30 P.M.	Aug. 13, '55	35	DCE

[17]Table I gives full data on all feeding records obtained during this study. The words _same individual_ appear in place of the data normally recorded under number and sex when the same individual fed on two or more plants during one observation. Either a question mark or the word _nymph_ may also be used in this column in cases when the sex of the feeding individual was not noted or the insect was immature. An asterisk is appended to the name of the food when it was nibbled rather than eaten; nibbling is here defined as feeding for a time so short as to result in negligible damage to the food. The time of feeding indicated is approximate. The abbreviation _M._, listed in the time column, refers to a time during the noon hour. A total of 27 feeding records for _Arphia sulphurea_ and 39 for _Atlanticus testaceus_ have been withheld but will be presented in later papers. All doubtful records have been deleted from the above. The observers of feeding records are indicated by their initials. These persons include the author, S.K. Gangwere, who personally amassed approximately two-thirds of the records; D.C. Eades, who contributed several feeding records; J.K. Hiltunen, the author's full-time research assistant during the 1959 season, who amassed more than one-fourth of the records; and A.M. Wenner, who was the author's research assistant during the 1958 season.

The following example will illustrate the way in which data provided in Table I may be evaluated in terms of food availability. In Table I it is noted that over forty individuals of _Conocephalus attenuatus_ were observed feeding on _Eupatorium perfoliatum_, one on _Scirpus atrovirens_, and one on _Juncus effusus_. By turning to the lists of relative abundance of plant species provided in Appendix B, it is seen that the first of these food-plants, _Eupatorium_, is common, but not abundant, at Station 29, the site of these particular feeding

TABLE I (CONT.)
FEEDING RECORDS TAKEN IN NATURE

records. Thus, the marked preference of Conocephalus for this plant is significant, though probably dependent in part on a change in the plant's seasonal condition; often, when plants newly flower, they are unusually attractive to certain feeders. Juncus effusus, an abundant plant at Station 29, was chosen but once, contrasting sharply with Eupatorium, indicating that its preference value is low. The Scirpus record may or may not be significant, for this plant was not abundant enough to have been recorded when the list of plants was made. Nevertheless, by virtue of its comparative scarcity at Station 29, it cannot be a major factor in the diet of Conocephalus, even if its preference value happens to be high.

TABLE II[18]
RESULTS OF DIFFERENTIAL FEEDING TESTS

1. _Diapheromera femorata_
(Tested early September to middle October)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	67V[19] / 79V / Untouched: 60, 61, 109, 110, 111, 118, 146, 161, 175
Test II.	67V / 112VN[20] / Untouched: 63, 68, 79, 84, 104, 105, 109, 119
Test III.	67V / 63V / 58V / Untouched: 51, 55, 66, 84, 119
Test IV.	66V / 86V / 79V / 112VN & 68VN / Untouched: 84, 105, 146
Test V.	86V / 67V / 119V / Untouched: 109, 123
Test VI.	86V / 62V / 112V / 68V / Untouched: 109, 146
Test VII.	86V / 65VN / 67VN
Test VIII.	63V / 86VN

B. Summary of Relative Preference Value of Frequently Tested Foods:

Rubus occidentalis V 4:1[21]/ Quercus velutina V 4:1 / Hamamelis virginiana V 2:1 / Tilia americana V 1:2 / Ulmus rubra V 1:2 & Cornus stolonifera V 1:2

2. _Chloealtis conspersa_
(Tested early July to early August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	27VF[22]/ 17VF / 29VF / 24F / 162FN / 97FN / Untouched: 74, 76, 114, 148, 165, 174
Test II.	10VF / 17V / 29VF / 27VF / 25F / 45V / 100VN / 99FN / Untouched: 81, 95, 117, 142, 144, 148, 174, 182
Test III.	14V / 16V / 28F / 45V & 29F / 176VN & 96VN / Untouched: 48, 95, 113, 134, 142, 148, 162, 165
Test IV.	14V / 16V / 28VF / 29VF / 45V / 162VN / Untouched: 48, 95, 96, 113, 134, 142, 148, 165, 176
Test V.	16V / 14VF / 10V / 29VF / 28VF / Untouched: 48, 96, 134, 148, 162, 165, 176, 178

[18] See pp184-186for a discussion of the formulation and use of the following data.

[19] _67_, as seen in Appendix C (Plants Used In Study), refers to _Quercus velutina_, while V refers to eating of vegetative parts.

[20] _N_ refers to nibbling rather than eating.

[21] 4:1 is the ratio of acceptances to rejections or nibbling.

[22] _F_ refers to eating of floral parts.

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test VI.	27VF & 17V & 45VF & 29VF / 99V / 81VN / Untouched: 49, 89, 98, 135, 144, 148, 178
Test VII.	29VF & 27VF / 17VF / 45V/Untouched: 49, 81, 144, 148, 174, 176, 178
Test VIII.	29VF & 27V / 45V / 17V / 174VFN / Untouched: 86, 99, 117, 134, 135, 144, 148, 162, 165
Test IX.	29VF & 45V / 17V / 24V / Untouched: 89, 117, 135, 144, 148, 149, 174, 179
Test X.	10VF / 16V / Untouched: 89, 96, 115, 117, 134, 149, 165, 168, 178, 181
Test XI.	16VF / 17VF / 45V / Untouched: 49, 117, 135, 165, 174, 178
Test XII.	16V / 14V & 10V / 28VF / Untouched: 49, 117, 135, 165, 174
Test XIII.	31V / 29V / 28VF / Untouched: 4, 17, 63, 134, 159
Test XIV.	31V & 29V / 28VF / Untouched: 4, 17, 63, 134, 159
Test XV.	31V & 28VF & 17V / Untouched: 63, 134, 159
Test XVI.	29V / 31V / 28VF / 17V / Untouched: 4, 63, 134
Test XVII.	29V / 31V / 28VF / Untouched: 4, 17, 63, 134, 159

B. Summary of Relative Preference Value of Frequently Tested Foods:

Dactylis glomerata V 6:0 / Poa pratensis VF 12:0 & Phleum pratense VF 6:0 & Carex communis V 5:0 / Poa compressa VF 9:0 / Juncus tenuis V 8:0 & Danthonia spicata V 9:3 / Chrysanthemum Leucanthemum VF 0:5 & Rudbeckia serotina VF 0:7

3. Chorthippus longicornis
(Tested middle September to early October)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	33V / 16V / 17V & 28V / 12V / 138VFN & 117FN & 30VN / 21FN & 159VFN & 153FN / Untouched: 81, 111, 113, 144, 148, 168, 179
Test II.	35V / 15V / 7V / Untouched: 59, 82, 87, 108, 109, 159, 160
Test III.	16V / 28V / 19V & 14V / Untouched: 95, 119, 134, 149, 153, 159, 176
Test IV.	16V / 28VF / 6V / Untouched: 1, 93, 148, 153, 168, 176, 178, 179
Test V.	17V / 16V & 33V / 21F / Untouched: 48
Test VI.	39V / 22V & 38VF & 34V / 7VN / 46VN / Untouched: 41, 72, 154, 156, 167
Test VII.	17V & 33V & 16V / 21FN
Test VIII.	14V & 16V / 28V / 12VN

B. Summary of Relative Preference Value of Frequently Tested Foods:

Carex pennsylvanica V 3:0 & Dactylis glomerata V 6:0 & Danthonia spicata V 3:0 / Poa compressa V 4:0 / Eragrostis spectabilis F 1:2 / Aster laevis F 0:3 & Aster sagittifolius VF 0:3

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

4. Orphulella speciosa
(Tested middle July to early August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I. 10VF / 29VF / 28F / 134V / 1VN / 174FN & 165FN / Untouched: 2, 83, 91, 93, 96, 148, 162, 178, 179
Test II. 10V / 28F / 1V / Untouched: 91, 93, 96, 134, 165, 174, 178, 162
Test III. 10V / 28V / Untouched: 1, 134, 140, 162, 174, 178
Test IV. 29VF / 17V / 25V / 45V / Untouched: 92, 117, 135, 144, 149, 174, 179
Test V. 10VF / 16V / Untouched: 92, 96, 115, 117, 134, 149, 165, 168, 178, 181
Test VI. 10V / 27VF / Untouched: 92, 113, 115, 140, 144, 168, 178, 181
Test VII. 14V & 16V / 21V / 99VN / 98VN / Untouched: 117, 142, 144, 148, 149, 182

B. Summary of Relative Preference Value of Frequently Tested Foods:

Agropyron repens V 5:0 / Poa compressa VF 3:0 / Equisetum arvense V 1:2 / Monarda fistulosa V 1:3 / Erigeron strigosus F 0:3 & Rudbeckia serotina F 0:4

5. Pseudopomala brachyptera
(Tested early to late July)

A. Tabular Synopsis of Differential Feeding Tests:

Test I. 28VF & 10VF / 96VF / 97F / Untouched: 1, 2, 83, 125, 134, 148, 165, 174
Test II. 10VF / 28F / 96FN & 134VN / Untouched: 1, 2, 83, 148, 165, 174
Test III. 10V / 28F / 29F / Untouched: 1, 2, 70, 83, 96, 134, 148, 162, 165, 174, 178
Test IV. 10VF / 28F / 29VF / Untouched: 96, 134, 148, 162, 165, 174, 178
Test V. 10V / 28VF / 29VF / Untouched: 83, 96, 134, 148, 162, 165, 174, 178
Test VI. 10V / 29VF / 28VF / Untouched: 83, 96, 134, 148, 162, 165, 174, 178
Test VII. 10VF / 29VF / 28F / Untouched: 83, 91, 93, 96, 134, 148, 162, 165, 174, 178, 179
Test VIII. 10V / 28F / Untouched: 1, 91, 93, 96, 134, 162, 165, 174, 178
Test IX. 35V & 34V / 36V / 22V / 39V / 38VN & 45VN & 11VN / Untouched: 40
Test X. 35V & 10V / 1V & 28F & 11F / 7 VN / Untouched: 44, 45
Test XI. 35V & 10V / 28VF & 11V & 1V / 7 VN / 45VN
Test XII. 35V & 10V / 11VF & 1V / 28VN / 7VN / Untouched: 45
Test XIII. 35V & 10V / 1V / 28V / 11VN / Untouched: 7, 45

B. Summary of Relative Preference Value of Frequently Tested Foods:

Agropyron repens V 12:0 & Carex stricta var. strictior V 5:0 / Poa compressa VF 11:1 / Agrostis alba VF 3:2 & Poa pratensis VF 5:0 / Juncus tenuis V 0:5 / Melilotus alba VF 1:7 & Monarda fistulosa V 0:8

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

6. Syrbula admirabilis
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	14V & 16V & 28VF & 10V
Test II.	28V & 10V / 1V / Untouched: 91, 111, 140, 174, 178, 179
Test III.	12VF & 16V & 29VF / Untouched: 101, 111, 144, 149, 168, 174
Test IV.	10V & 16V / 28VF / 29F / 1VN / Untouched: 91, 93, 111, 115, 117, 148, 149, 168, 178, 179
Test V.	16V & 10V / 28VF / 1V / 138VFN & 93VN / Untouched: 91, 111, 115, 117, 148, 168, 178, 179
Test VI.	13VF / 29VF / 28VF / 25VN / Untouched: 92, 93, 103, 104, 170, 172, 178, 179, 180
Test VII.	10V / 28VF / 1VN / Untouched: 2
Test VIII.	16V / 21VF & 28VF / 30F / 12F & 29F / 179VN & 117FN / Untouched: 48, 144
Test IX.	13VF / 28V / Untouched: 67, 91, 93, 104, 172, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Dactylis glomerata V 5:0 & Agropyron repens V 5:0 / Poa compressa VF 8:0 / Poa pratensis VF 4:0 / Equisetum arvense V 2:2 / Lespedeza capitata V 0:4 & Solidago nemoralis V 0:6

7. Arphia p. pseudonietana
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	10V & 29F / 28V / 1V / Untouched: 91, 93, 113, 115, 125, 140, 148, 168, 174, 178, 179, 184
Test II.	10V & 16V & 28VF / 29F / 115F & 117F / 1VN / Untouched: 91, 93, 111, 148, 149, 168, 178, 179
Test III.	28V / 16V & 10V /1V / 117FN / 93VN / Untouched: 91, 111, 115, 138, 148, 168, 178, 179
Test IV.	28VF / 13VF / 25V /67VN / 37VN & 179VN /Untouched: 93, 115, 140, 168
Test V.	28VF / 10V / 1V / Untouched: 2, 91, 93, 117, 134, 138, 148, 164, 176, 178, 179
Test VI.	16V / 21F / 28FN & 138FN / 117FN & 30FN / Untouched: 115, 140, 149, 168, 176
Test VII.	10V / 14V & 28VF / 138VF / 178VN / 179VN / Untouched: 1, 91, 93, 117, 148, 163, 182
Test VIII.	16V / 10V & 28F & 1V / Untouched: 91, 93, 117, 119, 148, 178, 179
Test IX.	13VF / Untouched: 28, 67, 91, 93, 104, 172, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Dactylis glomerata V 4:0 / Agropyron repens V 6:0 & Poa compressa VF 7:2 / Equisetum arvense V 4:2 / Linaria vulgaris VF 1:3 & Daucus Carota F 1:5 / Oenothera biennis F 1:4 & Solidago juncea V 0:6 & Solidago nemoralis V 0:8 & Lespedeza capitata V 0:8

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

8. Arphia sulphurea
(Tested early June to middle July)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	29VF / 28VF / 134VN / 70VFN / 183VN / Untouched: 117, 151, 170, 178, 180
Test II.	29VF / 28VF / 134V / 183VN / 70FN / Untouched: 151, 170
Test III.	28VF / 29VF / 151F / Untouched: 70, 134, 148, 162, 180
Test IV.	28VF / 180VN / Untouched: 70, 134, 148, 162
Test V.	10V / 28VF / Untouched: 70, 83, 148, 162, 180, 184
Test VI.	10V / 28F / 165FN / Untouched: 1, 2, 70, 83, 96, 148, 184
Test VII.	27V & 16V / 25F / 29VN / 99VN / 96VN / Untouched: 70, 88, 95, 103
Test VIII.	10VF / 27VF / 29VF / 17V & 25VF / 45V / 148VF & 144F / 174F / 142F / 182V / 100V / Untouched: 81, 95, 99, 117
Test IX.	16V / 10VF / 25VF / 33V / 28VF & 45V & 17VF
Test X.	27V / 16V / 25F / 29V
Test XI.	10VF / 29VF / 25F / 17VF / 45V & 27V
Test XII.	29VF & 14V / 28F & 16V / 45V / 48V & 162F & 95V / Untouched: 113, 134, 142, 148, 165, 176
Test XIII.	16V / 14V / 29VF / 28F / 45V & 95V & 48V / 162V / Untouched: 113, 134, 142, 148, 165, 176
Test XIV.	16V / 14VF / 10V / 29FN & 28FN / 142FN & 48VN / Untouched: 134, 148, 162, 165, 176, 178
Test XV.	27VF / 17V / 29F / 45V / 144V / 89V / 98VN / Untouched: 49, 81, 99, 135, 148, 164, 176, 178
Test XVI.	27VF / 17VF / 29VF / 45V & 81V / Untouched: 49, 144, 148, 174, 176, 178
Test XVII.	100V & 99V / 70VF / 109VN & 88VN / Untouched: 103, 104, 140, 148, 176
Test XVIII.	70F / 99VN / 100VN & 95VN / Untouched: 88, 148
Test XIX.	29V / 28F / 70F / 93VN / Untouched: 178, 179, 180
Test XX.	29V / 27V / 28FN & 70VN / 134VN / Untouched: 85, 93, 178, 179, 180
Test XXI.	27VF / 29V / 28F / 70F / 85VN / Untouched: 93, 134, 162, 165, 178, 179, 180
Test XXII.	29V / 27VF / 28FN / Untouched: 85, 93, 134, 162, 165, 178, 179, 180
Test XXIII.	29V / 27V & 28F / Untouched: 85, 93, 134, 162, 165, 178, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Dactylis glomerata V 6:0 / Agropyron repens VF 6:0 / Phleum pratense VF 10:0 & Poa pratensis VF 15:2 / Panicum sp. F 5:0 / Danthonia spicata VF 5:0 & Poa compressa F 12:3 / Juncus tenuis V 7:0 / Trifolium pratense V 1:4 & Rumex Acetosella VF 4:8 & Medicago lupulina V 2:3 / Chrysanthemum Leucanthemum F 2:7 / Monarda fistulosa V 1:10 / Erigeron strigosus F 0:7 & Lespedeza capitata V 0:5 / Solidago rigida V 0:9 & Achillea Millefolium VF 1:11

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

9. *Camnula pellucida*
(Tested July)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	29V / 28F / 27V / 134VN / 178VN / Untouched: 85, 93, 162, 165, 179, 180
Test II.	29V / 27VF / 28VF / 85VN / 13VN / Untouched: 93, 134, 165, 178, 179, 180
Test III.	29V / 27VF / 28F / 164VN / 13VN & 85VN Untouched: 93, 134, 165, 178, 179, 180
Test IV.	10VF / 28F & 27V / 178VN / Untouched: 93, 134, 165, 179, 180
Test V.	29V & 27VF / 28VF / 13VN / Untouched: 85, 93, 134, 165, 178, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Poa pratensis V 4:0 / Phleum pratense VF 5:0 / Poa compressa F 5:0 / Aristida purpurascens V 0:3 & Rubus flagellaris V 0:4 / Solidago juncea V 0:5 & Monarda fistulosa V 0:5

10. *Chortophaga viridifasciata*
(Tested middle May to middle July)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	164V / 182VF & 143V & 129V / 83VN
Test II.	164V / 182V & 143V & 129V / 99VN / 83VN
Test III.	78VF & 164V / 133V / 99V / 117VN / 129FN / 83VN / Untouched: 176
Test IV.	78VF / 99V / 164V / 133V / 129F / 117VN & 176VN / Untouched: 83
Test V.	164V / 133V & 129V / 99V / 117V / 176VN / 83VN
Test VI.	164V/ 99V / 83V / 117VN / 176VN
Test VII.	164V / 134V / 99V / 117V / 81VN
Test VIII.	164V / 117VF / 81V / 176VN
Test IX.	33V / 134V / 99V / 50VN / 176VN / 148VN
Test X.	53V / 165F / 134V / 96V / 148V / Untouched: 176
Test XI.	134V / 96VN / 162VN / 165FN / 148VN
Test XII.	48V / 134V / 162F / 176V / 95VN / Untouched: 148, 165
Test XIII.	96F / 134V / 142F / 48V / Untouched: 83, 95, 148, 162, 165, 174
Test XIV.	48V / 97VF / 96V / 134V / 174FN / Untouched: 95, 113, 117, 148, 149, 162, 165
Test XV.	48V / 142F / 96F / Untouched: 83, 95, 113, 117, 134, 148, 162, 165
Test XVI.	16VF / 14VF & 27VF / 29VF & 25VF / 33V / 28VF / 45V
Test XVII.	16VF & 14VF / 27V / 33VF / 28F / 29V / 25VF / 45V
Test XVIII.	29V & 16V & 14V / 33VF & 28VF / 25VF / 45V
Test XIX.	29VF / 16V / 14V / 28F / 45V
Test XX.	16V / 14V / 28F / 29VF & 96V & 48V / Untouched: 45, 95, 113, 134, 142, 148, 162, 165, 176
Test XXI.	16V / 14V / 29VF & 28VF / 48V & 96VF / 95V/ 142FN & 134VN & 45VN / Untouched: 113, 148, 162, 165, 176

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test XXII. 14VF / 16V / 10V & 29VF / 28F / 134F & 96VF / 48V & 162F / Untouched: 148, 165, 176, 178
Test XXIII. 14VF / 16V / 29VF & 28F / 96VFN & 95VN / Untouched: 48, 104, 134, 148, 162, 165, 176, 178
Test XXIV. 27V / 16V / 14V / 134VN & 29VFN / 48VN & 28FN / 165FN & 95VN / Untouched: 96, 104, 135, 148, 162, 176, 178
Test XXV. 14VF / 78VF
Test XXVI. 29VF / 170V / Untouched: 151, 172, 178, 180
Test XXVII. 29V / 28F / 70F / Untouched: 93, 178, 179, 180
Test XXVIII. 29V / 27V / 28F / 85V / 70VFN / 178VN & 93VN / Untouched: 134, 179, 180
Test XXIX. 29V / 27V / 70VF / 28F / Untouched: 85, 93, 134, 162, 165, 178, 179, 180
Test XXX. 27V & 29V / 28F / 162V / 93VN & 85VN / 178VN / Untouched: 134, 165, 179, 180
Test XXXI. 29V / 27V / 28F / 93VN / 162VN / Untouched: 70, 85, 134, 165, 178, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Dactylis glomerata V 9:0 / Bromus inermis VF 10:0 / Phleum pratense V 7:0 & Poa pratensis VF 14:1 / Poa compressa F 13:1 / Cirsium arvense V 8:0 / Asparagus officinalis V 7:2 & Melilotus alba VF 7:3 / Juncus tenuis V 4:2 / Lespedeza capitata V 0:5 / Monarda fistulosa V 8:9 & Glechoma hederacea VF 4:1 / Medicago lupulina V 1:7 / Daucus Carota V 3:5 & Chrysanthemum Leucanthemum VF 3:10 / Erigeron strigosus F 1:13 & Solidago juncea V 0:9 / Potentilla recta V 1:7 & Solidago canadensis V 1:12 & Achillea Millefolium V 1:11

11. Dissosteira carolina
(Tested early August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I. 10VF / 29VF & 1V / 28F / 91VN / 96VN & 149VN / Untouched: 2, 117, 125, 134, 140, 148, 157, 178, 179
Test II. 16V & 10VF / 96VF / 115F & 181F / 149VN / Untouched: 117, 134, 165, 168, 178
Test III. 10V / 27V / 144V / 181F / Untouched: 113, 115, 140, 168, 178
Test IV. 14VF & 28F & 27V & 10V / 144V & 16V & 101V / 30V / 149VN & 181FN / 178VN / Untouched: 117, 148, 168
Test V. 10V / 28F & 1V / 174F & 140V /111V / 91VN / Untouched: 157, 178, 179
Test VI. 10V / 28F & 1V / 91V / 29F / 113V & 174F / Untouched: 93, 115, 125, 140, 148, 168, 178, 179, 184
Test VII. 10V & 16V / 28VF & 1V / 29F & 111V / 117FN & 91VN & 93VN & 178FN / 168VN & 115FN & 149VN / Untouched: 148, 179
Test VIII. 28F & 10V / 16V & 19VF / 30VF & 18F & 117F & 1V / 91VN & 111VN / 93VN & 178VFN & 12FN & 138FN / Untouched: 115, 148, 168, 179
Test IX. 28VF / 25V & 37VF / 13VF / 93VN / 179VN & 140VN / Untouched: 67, 115, 168
Test X. 28V / 93VF / 172VN / Untouched: 13, 67, 91, 104, 179, 180

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

B. Summary of Relative Preference Value of Frequently Tested Foods:

Agropyron repens V 8:0 / Poa compressa F 8:0 & Equisetum arvense V 5:0 / Desmodium illinoense V 1:5 & Daucus Carota F 1:4 & Lespedeza capitata V 1:4 & Verbascum Thapsus V 1:4 / Solidago juncea VF 0:8 & Oenothera biennis F 1:5 / Solidago nemoralis V 0:7 & Gnaphalium obtusifolium V 0:7

12. Encoptolophus s. sordidus
(Tested middle September to early October)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	33V / 16V & 17V / 12V & 28VF / 117F & 21F / 30VN / 153VN & 111VN / Untouched: 81, 113, 138, 144, 148, 159, 168, 179
Test II.	13VF / 28V / 172FN & 93VN / 67VN / Untouched: 91, 104, 179, 180
Test III.	19V / 28V & 14V / 16V / 95VN / Untouched: 119, 134, 149, 153, 159, 176
Test IV.	16V / 28V / 1V / Untouched: 93, 148, 153, 168, 176, 178, 179
Test V.	33V / 16V / 17V / 21F / Untouched: 48
Test VI.	16V / 28VF / 10VN / 1VN / Untouched: 111, 117, 138, 148, 153, 178, 179, 180
Test VII.	33V / 16V / 17V / 21VFN
Test VIII.	16V & 14V / 28VF / 12VF

B. Summary of Relative Preference Value of Frequently Tested Foods:

Carex pensylvanica V 3:0 / Dactylis glomerata V 7:0 / Danthonia spicata V 3:0 / Poa compressa VF 6:0 / Eragrostis spectabilis F 2:1 / Aster laevis V 0:4

13. Pardalophora apiculata
(Tested middle May to middle June)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	151V / 70VF / 183VN / 170VN / 172VN / Untouched: 178
Test II.	151VF / 70VF / 183VN & 172VN & 170VN / Untouched: 178
Test III.	151VF / 70VFN / 183VN & 172VN & 117VN & 134VN / Untouched: 170, 178, 180
Test IV.	134V / 117V / 183V / 70F / 151F / Untouched: 170, 172, 178, 180
Test V.	134V / 183V / Untouched: 70, 117, 170, 172, 178
Test VI.	70F / 151F / 134VN / 162FN / Untouched: 83, 148, 164, 180
Test VII.	162FN / 70FN / Untouched: 83, 134, 148, 180
Test VIII.	28V / 29V / 183V & 70F / 170V / 151VN / 178VN / Untouched: 172
Test IX.	29V / 28V / 183V / 151V / 70F / 170V / 178VN / Untouched: 172

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test X.	29V / 28V / 183V / 70VF / 134V / 74V / 117VN / Untouched: 151, 170, 172, 178, 180
Test XI.	29V / 28V / 183V / 151VF / 70VF / 117V / 178VN / 134VN / Untouched: 74, 170, 172, 180
Test XII.	29V / 28V / 134V / 70V / Untouched: 117, 170, 172, 178, 180
Test XIII.	29V / 28V / 151V / 162V / 70VN / Untouched: 83, 134, 148, 180
Test XIV.	28V / 162FN / 148FN / 70FN / Untouched: 83, 134, 180
Test XV.	28V / 29V
Test XVI.	29V / 28V
Test XVII.	29V / 28V
Test XVIII.	29V / 28V
Test XIX.	29V / 28V
Test XX.	29V / 28V
Test XXI.	28VF & 151VF / 170V / Untouched: 172, 178, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Poa pratensis V 12:0 / Poa compressa V 14:0 / Tragopogon pratensis V 6:3 & Antennaria fallax VF 9:2 / Rumex Acetosella VF 9:5 / Monarda fistulosa V 4:6 / Daucus Carota V 2:4 / Hieracium longipilum V 3:8 / Solidago juncea V 0:11 & Liatris aspera V 0:11.

14. Spharagemon b. bolli
(Tested early July to late August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	10V / 28F & 29F & 1V / 96VF / 140VN & 91VN / Untouched: 2, 83, 113, 93, 134, 148, 162, 165, 174 178, 179
Test II.	10VF / 1V/29VF / 28F & 174F & 140V & 96VF / 134VF & 149V / Untouched: 117, 178
Test III.	10V / 92VF & 181VF / 16V / 117VF & 96VF / Untouched: 115, 134, 149, 165, 168, 178
Test IV.	10VF / 27VF / 140V / 144V/181F / Untouched: 92, 113, 115, 168, 178
Test V.	28F / 27V & 10VF & 30V & 14VF & 181VF / 16V & 101V / 144V / 178VN & 149VN / Untouched: 117, 148, 168
Test VI.	10V & 140V / 111V / 28F & 1V / 174FN & 91VN / Untouched: 178, 179
Test VII.	16V / 144V / 117F & 101V & 29F / 174F & 12F / 111VN / Untouched: 149, 168
Test VIII.	10V / 16V & 28F / 1V / 111V & 29F / 117FN & 91VN & 149VN / 115FN & 93VN / Untouched: 148, 168, 178, 179
Test IX.	1V & 138VF / 10V & 16V / 28F & 91V & 117F / 93VN & 111VN / Untouched: 115, 148, 168, 178, 179
Test X.	28F / 25V & 140V / 13VF / 93V & 37VF / 67VN / 179VN & 115VFN / Untouched: 168
Test XI.	93VF / 172VN / 104VN / Untouched: 13, 28, 67, 91, 179, 180
Test XII.	27V & 28VF / 29F / 93VN/134VN / 179VN / Untouched: 13, 85, 165, 178, 180
Test XIII.	27VF / 28F / 29V / 164VN / Untouched: 13, 85, 93, 134, 165, 178, 179, 180

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test XIV.	27V / 28F / 10V / 93VN / 179VN / Untouched: 134, 165, 178, 180
Test XV.	27VF & 28VF / 178VN & 29VN & 85VN & 165VFN & 13VN / Untouched: 93, 134, 179, 180
Test XVI.	27VF / 28VF/ 134V / 93VN / 29VN / Untouched: 13, 85, 165, 178, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Phleum pratense VF 7:0 & Agropyron repens V 9:0 / Equisetum arvense V 5:0 & Dactylis glomerata V 5:0 & Poa compressa F 12:1 / Poa pratensis VF 6:2 / Verbascum Thapsus V 4:1 / Daucus Carota F 3:3 / Desmodium illinoense V 1:4 & Ambrosia artemisiifolia V 1:4 & Lespedeza capitata V 2:8 & Monarda fistulosa V 2:6/ Aristida purpurascens VF 1:5 & Oenothera biennis VF 0:5 & Solidago nemoralis V 0:11 & Erigeron strigosus VF 0:7 & Solidago juncea V 0:13

15. <u>Spharagemon collare</u>
(Tested middle July to early September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	10V & 1V & 91V / 28F & 113V & 174F & 93V / 140VN / Untouched: 29, 115, 125, 148, 168, 178, 179, 184
Test II.	16V & 10V / 28F / 29F & 1V / 117F & 115F / 149VN / 93VN / 91VN / Untouched: 111, 148, 168, 178, 179
Test III.	16V / 28V / 117F & 1V & 138VF & 91V & 10V / 93V & 111V / 178FN / Untouched: 115, 148, 168, 179
Test IV.	28VF / 25V & 37VF & 93V / 13F / 115FN & 179VN & 67VN / Untouched: 140, 168
Test V.	28F & 10V & 1V / 93V & 164F & 91V / 138VFN / Untouched: 2, 117, 134, 148, 176, 178, 179
Test VI.	16V / 28F / 21VF / 138VFN & 30VFN / 117FN / Untouched: 115, 140, 149, 168, 176
Test VII.	28VF / 14V / 91V & 1V / 10V & 93V / 138VN / 117FN & 163VN / Untouched: 148, 178, 179, 182
Test VIII.	16V / 10V & 119V / 1V & 91V / 93V / 28FN / Untouched: 117, 148, 178, 179
Test IX.	28VF & 13VF / 93VF / 172VN / Untouched: 67, 91, 104, 179, 180
Test X.	27VF / 28F / 29F / 93V / Untouched: 85, 134, 162, 165, 178, 179, 180
Test XI.	27VF / 28F / 29F / 93VN / 134VN / Untouched: 13, 85, 165, 178, 179, 180
Test XII.	27VF / 28F & 29F / 164VN / 134VN / 179VN & 93VN & 13VN / Untouched: 85, 165, 178, 180
Test XIII.	27VF & 10VF / 28F / 93V / Untouched: 134, 165; 178, 179, 180
Test XIV.	27VF / 28VF / 29F / 13V / 93VN / 85VN / Untouched: 134, 165, 178, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Phleum pratense VF 5:0 & Agropyron repens V 7:0 / Poa compressa F 13:1 / Equisetum arvense V 6:0 / Poa pratensis F 5:1 & Desmodium illinoense V 5:2 / Lespedeza capitata V 9:4 / Daucus Carota F 2:4 / Monarda fistulosa V 0:6 / Oenothera biennis F 1:4 / Solidago juncea F 0:11 & Solidago nemoralis V 0:13

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

16. *Melanoplus b. bilituratus*
(Tested early July to middle August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	28VF & 10V / 97VF / 134V & 96VF / 162FN / 165FN / Untouched: 1, 2, 83, 125, 148, 174
Test II.	10V / 28VF / 134V / 96VF / 1V / 174F / 2F & 165F & 83F & 148VF & 162F / 70VN
Test III.	10V / 29F / 178V & 28F / 96VF / 174F & 162F / 134V / 165F & 83F & 148V / Untouched: 1, 2, 70
Test IV.	10VF / 28F & 29VF / 96VF & 174VF & 134V / 178V & 165F & 148V / Untouched: 70, 162
Test V.	10VF / 29VF / 96VF & 28F / 178V / 174F / 165FN & 134VN / 148VF / Untouched: 83, 162
Test VI.	10V / 162F / 29VF / 28VF & 96VF & 174F & 178V / 134VF / Untouched: 83, 91, 93, 148, 165, 179
Test VII.	10VF / 29VF & 178V / 96VF / 28F & 134VF / 174F & 83F & 165F & 162F / Untouched: 91, 93, 148, 179
Test VIII.	10V / 28F & 162F & 178V / 165F & 174VF / 1V / 134VFN & 96VFN / Untouched: 29, 83, 91, 93, 148
Test IX.	10V / 1V / 178V / 28F & 174F & 134F & 162V / 29V / 140VN
Test X.	10V / 1V / 29VF / 96VF & 178VF & 134F & 174VF / 28FN & 140VN & 149VN / Untouched: 117
Test XI.	10V / 96VF / 16V / 134VF & 181F / 92VFN & 149VN & 165FN & 178VFN / 115VN & 168VN / 117FN
Test XII.	14VF / 16V / 28VF
Test XIII.	179F / 180F / 93V / 172FN / 91VN / Untouched: 13, 28, 67, 104
Test XIV.	29V / 27VF / 28VF / 134V & 165F / 178VN / 85VN / Untouched: 13, 93, 179, 180
Test XV.	27VF / 29V / 28F / 85VN & 134VN & 164VN / Untouched: 13, 93, 178, 179, 180
Test XVI.	27V / 10V / 28F / 178VN & 165VFN / Untouched: 93, 134, 164, 179, 180
Test XVII.	27VF & 29V / 28VF / 134V / 85VN & 179VN & 178VFN & 165FN / Untouched: 13, 93, 180
Test XVIII.	27VF / 29V / 134VF / 28F & 178V / 85VN & 165VFN / 93VN / Untouched: 13, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Phleum pratense VF 5:0 & Agropyron repens V 12:0 / Poa pratensis VF 11:1 / Poa compressa F 15:2 / Melilotus alba VF 9:1 / Solidago juncea V 9:5 / Rudbeckia serotina F 9:1 & Monarda fistulosa VF 12:4 & Chrysanthemum Leucanthemum F 6:3 / Erigeron strigosus F 6:7 / Achillea Millefolium VF 4:4 & Potentilla recta F 3:4 / Solidago nemoralis VF 1:7 & Solidago rigida F 1:5 & Lespedeza capitata V 1:8

17. *Melanoplus bivittatus*
(Tested early August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	9V & 7V / 27V & 34V & 39V / 41F / 130VN & 166VN & 36VN / 72VN & 22VN & 38VN / Untouched: 11, 45, 46, 106, 122, 124, 132, 139, 154
Test II.	9V / 44V / 38V / 7V & 167V / 11F & 36V / 139VFN & 130VN & 22VN & 39VN / Untouched: 45, 46, 72, 154
Test III.	9VF / 56V & 11F / 39V / 166V / 126VF / 36VN / Untouched: 34, 46, 124, 139, 167, 181

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test IV.	9V / 7V / 11F & 56V & 130V & 55V / 36VFN & 39VN / 167VN & 34VN / 72VN / Untouched: 46, 106
Test V.	7V & 9V / 11F / 38VF & 167F & 166VF & 55V / 72V & 39VF & 46F / 176VFN & 41FN & 34VN & 36VN
Test VI.	9V / 7V / 41F & 166VF / 22V & 117F & 167VF & 55V / 34VN & 11FN / 36VN & 46VFN & 39VN
Test VII.	108V & 7V / 116F & 87F & 136V / 167VF / 109V / 15VF / 56VN & 160VFN / 3VN & 59VN / 82VN & 35VN
Test VIII.	9V / 117F & 7V / 167VF & 166VF / 39V & 176V & 36V & 181F / 11FN / Untouched: 22, 38, 41, 46
Test IX.	9V / 181F / 117FN & 41FN & 22FN / 7VN & 39VN & 72VN & 176FN & 166FN & 56VN / Untouched: 36, 46, 122, 167
Test X.	108V / 82F / 7V & 35V / 109VN & 87VN / 159VN / Untouched: 15, 59, 160

B. Summary of Relative Preference Value of Frequently Tested Foods:

Sagittaria latifolia V 8:0 / Typha latifolia V 8:1 / Eupatorium perfoliatum VF 4:2 / Eupatorium purpureum VF 5:3 & Agrostis alba F 4:3 / Scirpus atrovirens V 4:4 / Carex vulpinoidea V 2:6 & Carex retrorsa V 1:4 & Tovara virginiana V 1:4 / Juncus Torreyi VF 1:7

18. Melanoplus confusus
(Tested early July to early August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	10VF / 28VF / 97VF & 96VF / 162F / 165F / 148V & 174F & 125V & 2F / 134VN & 1VN / Untouched: 83
Test II.	28VF & 10VF / 165VF & 162VF & 1V & 96VF & 70VF / 134V & 148VF & 83F & 174VF / Untouched: 2
Test III.	10VF / 29F / 28F & 70VF & 165F & 162F / 174VF & 178V / 96VF & 1V & 134V / 2FN & 83FN & 148FN
Test IV.	10VF / 28VF & 178V & 29VF & 162VF / 174F / 96VF & 165F / 148VF / Untouched: 134
Test V.	10V / 162VF / 29VF & 178V / 96VF & 174VF / 165F & 134V & 28VF / 148V
Test VI.	10VF / 29VF & 162VF & 174VF / 96VF & 178V / 134VF / 165F & 28VF / 148V / Untouched: 83, 93, 179
Test VII.	10VF & 29VF / 162F & 178V / 28F & 174F / 96VF & 134F / 165F / Untouched: 83, 91, 93, 148, 179
Test VIII.	10VF & 162F & 178V / 174F / 28F & 96VF & 1V / 165F / 134FN & 93VN / Untouched: 91
Test IX.	10VF & 178V / 1V & 174F & 162VF / 28VF & 134 F / 29V / Untouched: 140
Test X.	10VF / 178VF / 174F & 1V & 117F /134V & 149V & 96VF / 28FN & 29FN / Untouched: 140
Test XI.	10V & 181VF / 115F & 92VF & 117F & 96VF / 134VF / 16VN & 149VN & 165FN / Untouched: 168, 178
Test XII.	16V / 28FN & 14VN
Test XIII.	1V & 48V / 96VF / 174VF / 178V / 162F & 165F / 134V / 83FN / Untouched: 2, 70, 148
Test XIV.	162F / 174F / 134V & 178V / 165F & 96VF / 1V & 83F / 148FN / Untouched: 2, 70
Test XV.	29VF / 16V / 14V / 27V / 25F / 45VF / 17VF
Test XVI.	28F / 70F & 178V / 179V & 180V / 29VN / Untouched: 93
Test XVII.	27V / 28VF / 134V / 70V / 85V / 93VN & 178VN / 29VN & 179VN / Untouched: 180

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test XVIII.	27VF / 162F & 70VF / 178V & 134V / 165V / 28F / 179VN & 29VN / Untouched: 85, 93, 180
Test XIX.	27VF / 162VF / 178V & 134V / 85V / 165VFN / 28VN / 29VN / Untouched: 93, 179, 180
Test XX.	27VF / 162F & 134VF / 178V / 179V & 165VF / 93VN & 28VN & 29VN & 85VN / Untouched: 180
Test XXI.	27VF / 178V / 165F / 134V & 28VF / 179VN / Untouched: 13, 85, 93, 180
Test XXII.	27VF / 164V / 134VF & 165F / 178VN & 29VN & 85VN / Untouched: 13, 28, 93, 179, 180

B. Summary of Relative Preference Value of Frequently Tested Foods:

Agropyron repens VF 11:0 & Phleum pratense VF 7:0 / Chrysanthemum Leucanthemum F 14:0 / Solidago juncea V 15:3 / Rudbeckia serotina F 12:0 / Poa compressa VF 13:5 & Melilotus alba VF 12:0 & Erigeron strigosus F 14:2 & Equisetum arvense V 7:1 & Monarda fistulosa VF 16:3 / Achillea Millefolium VF 5:4 / Potentilla recta F 2:5 & Rubus flagellaris V 2: 4 & Solidago nemoralis V 2:7 / Equisetum hyemale F 1:4 & Lespedeza capitata V 0:10 & Solidago rigida V 1:6

19. Melanoplus *f.-r. femur-rubrum*
(Tested early September to early October)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	10V & 182VF & 117VF / 14V / 178V & 138VF & 111V & 174F / 134V / 28F & 164F & 163F / 1VN / 91VN & 179FN / Untouched: 2, 93, 115, 148, 168, 184
Test II.	117VF / 16V & 10V & 179VF / 119V / 178V / 91VN & 93VN / Untouched: 1, 28, 148
Test III.	179F / 180VF / 172VF / 91V / 13FN & 104VN / Untouched: 28, 67, 93
Test IV.	159F & 16V / 153F / 19VF & 14V / 95V & 134V / 176VFN / Untouched: 28, 119, 149
Test V.	153F / 176VF & 16V & 6V / 178V / 148VN / 93VN / Untouched: 1, 28, 168, 179
Test VI.	117V / 175VF & 153VF / 159F & 16V / 138F & 109V / 144VFN & 48VN / 17VN / 81VN & 21FN & 33VN / Untouched: 94, 114, 148
Test VII.	7V / 167V / 72V & 130V & 154VF / 156VF / 39VN / 46VN & 38VFN & 22VN / Untouched: 34, 41
Test VIII.	175VF & 16V / 159F & 99V / 153F & 156F / 138F / 144VN / Untouched: 17, 33, 81, 86, 148, 178

B. Summary of Relative Preference Value of Frequently Tested Foods:

Aster laevis F 4:0 & Dactylis glomerata V 5:0 / Solidago juncea V 3:1 / Solidago nemoralis F 2:2 / Lespedeza capitata V 0:4 & Achillea Millefolium V 0:5 & Poa compressa F 1:4

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

20. Melanoplus keeleri luridus
(Tested late August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	117VF / 1V / 16V & 178VF / 10V / 91V & 115F & 179F / 138VF / Untouched: 28, 93, 111, 148, 168
Test II.	180F & 170VF & 172F & 178VF / 28FN & 179VFN & 92VFN / Untouched: 13, 25, 93, 103, 104
Test III.	10V & 138VF / 1V & 117VF / 178VF & 134V / 164F / 176VFN / 179VFN & 91VN / Untouched: 2, 28, 93, 148
Test IV.	159F & 117F / 144VF & 142VF / 21F & 30F / 16V / 138F & 99VF / 179VFN & 149FN / 28FN / Untouched: 12, 48, 93
Test V.	182VF / 117F & 10V & 14V / 178V & 138VF / 91VN & 179FN / Untouched: 1, 28, 93, 148, 163
Test VI.	178V & 10V / 179F & 117F / 119VN / 16VN / Untouched: 1, 28, 91, 93, 148
Test VII.	172F / 179F / 180F / Untouched: 13, 28, 67, 91, 93, 104
Test VIII.	153F / 159F / 134V / 16V & 95V / 149VFN & 14VN / 19FN / Untouched: 28, 119, 176

B. Summary of Relative Preference Value of Frequently Tested Foods:

Daucus Carota F 5:0 / Solidago juncea VF 5:0 / Solidago nemoralis F 3:4 / Desmodium illinoense V 1:4 / Poa compressa F 0:8

21. Melanoplus s. scudderi
(Tested late August to late September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	99VF / 117F & 16V / 138VF & 159F / 142VF & 144VF / 28FN & 149VFN / 179FN & 12FN / Untouched: 21, 30, 48, 93
Test II.	117VF & 182VF & 10V / 178V / 138VF / 93V & 14V & 1V / 91VN & 28FN & 163FN / Untouched: 148, 179
Test III.	10V / 179VF & 16V / 178V & 117F & 119V / 93VN / 1VN / 91VN / Untouched: 28, 148
Test IV.	179F / 172F / 93V / 180F / 104VN / Untouched: 13, 28, 67, 91
Test V.	153F / 159F / 16V / 19V & 95V / 134V / 14VN / 149VFN & 176VFN / Untouched: 28, 119
Test VI.	153F / 16V / 176VF / 179VF & 178V & 148V / 93VN / Untouched: 1, 28, 168
Test VII.	175VF / 153F / 159F & 148V / 109VN & 138VFN & 144VN / 16VN & 17VN / Untouched: 21, 33, 48, 81, 94, 114, 117
Test VIII.	153VF / 10V / 138VF & 117F / 148VN / 178VN & 179FN / Untouched: 1, 28, 111, 180
Test IX.	176F / 99VF & 182V / 14V / 117VF / 16VN
Test X.	176VF / 182V / 14V / 117VF & 99VF / 16V

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

B. Summary of Relative Preference Value of Frequently Tested Foods:

Aster laevis F 4:0 / Solidago canadensis VF 3:1 & Daucus Carota VF 6:1 / Dactylis glomerata V 5:2 & Linaria vulgaris VF 3:1 & Solidago juncea V 3:1 / Solidago nemoralis F 3:3 / Lespedeza capitata V 2:3 & Achillea Millefolium V 2:3 & Equisetum arvense V 1:3 / Poa compressa F 0:7

22. Paroxya hoosieri
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	9V / 7V & 119V & 166V & 167VF & 11F / 38VF & 130VF / 126VN & 56VN & 139VFN / 39FN & 154VN / 36VN / Untouched: 22, 34, 46, 55, 72, 106, 122
Test II.	9V / 7V / 166VF & 167VF / 34V & 36V / 72VN & 176VN & 41VN / Untouched: 11, 38, 39, 46, 55
Test III.	9V / 166VF & 7V / 117F / 167VF / 22FN / Untouched: 11, 34, 39, 41, 46, 55
Test IV.	108V & 116F / 109V & 136V / 7V / 15VF & 82VF & 87F & 160VF / 59V & 167F / 56VN / 35VN / Untouched: 3
Test V.	9V / 7V & 117VF / 36V & 166VF & 167VF / 176V & 38V & 181F / 41FN & 22FN / Untouched: 11, 46
Test VI.	9V / 117F & 169F & 181F / 166V & 176F & 7V / 36VN / 46VN / Untouched: 22, 39, 41, 56, 72, 122, 167
Test VII.	160VF & 9V & 43V / 108VF / 166VF / 176VF / 7V & 131VF / 126VN & 32VN & 39VN/ Untouched: 44
Test VIII.	9V / 130VF / 181F / 176VF & 154VF & 177VF / 7VN & 117FN / 39VN / Untouched: 46, 54, 56, 72
Test IX.	160VF & 108V / 109V & 7V / 159FN / 15VN & 87VFN / Untouched: 35, 59, 82

B. Summary of Relative Preference Value of Frequently Tested Foods:

Sagittaria latifolia V 7:0 / Typha latifolia V 8:1 & Eupatorium perfoliatum VF 6:0 / Eupatorium purpureum VF 5:1 & Solidago canadensis VF 4:1 / Scirpus atrovirens VF 0:6 & Juncus Torreyi V 0:6

23. Schistocerca lineata
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	93V / 10V & 91V / 1V & 174V / 184VN & 28FN / Untouched: 29, 37, 113, 115, 125, 140, 148, 157, 168, 178, 179
Test II.	93V / 16V / 10V / 1V & 29F / 115VFN & 28FN / 117FN & 91VN & 111VN & 178FN / Untouched: 148, 149, 168, 179
Test III.	93V / 111V & 91V & 10V & 16V / 1V / 28F / 179VN & 115VN / Untouched: 117, 138, 148, 168, 178
Test IV.	103VF & 93VF & 104V / 92VF / 28F & 178F / 29FN / 13FN & 180VN & 179VN / Untouched: 25, 170, 172
Test V.	93VF / 91V / 10V & 1V / 138VF & 28VF / 176FN & 179VN / Untouched: 1, 2, 117, 134, 148, 178
Test VI.	16V / 140V / 30F / 149VFN / 138VN / Untouched: 21, 28, 115, 117, 168, 176
Test VII.	93VF / 163F / 14V / 138VF / 91VN & 1VN / 28FN & 10VN & 117FN / Untouched: 148, 178, 179, 182

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test VIII.	93VF / 119V / 16VN & 10VN / 91VN / Untouched: 1, 28, 117, 148, 178, 179
Test IX.	93VF / 67V & 104V / 91VN / Untouched: 13, 28, 172, 179, 180
Test X.	85V / 63V / 94VF & 93V & 30V & 104V & 103F / 179VN / Untouched: 13, 28, 134

B. Summary of Relative Preference Value of Frequently Tested Foods:

Lespedeza capitata VF 9:0 / Dactylis glomerata V 3:1 / Agropyron repens V 4:2 & Desmodium illinoense V 3:4 / Equisetum arvense V 4:2 / Linaria vulgaris VF 2:2 & Poa compressa F 3:7 / Oenothera biennis VF 0:4 / Daucus Carota F 0:6 & Solidago nemoralis V 0:9 & Solidago juncea F 1:6

24. Amblycorypha oblongifolia
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	178F & 169F / 134F & 141VF & 117F / 101VF & 111V & 113V & 119V & 110V & 109V / 146VN / Untouched: 14, 16, 36, 47, 174, 175
Test II.	119V / 178F & 109V & 115F & 101VF & 117VF / 111VN & 149VN / 110VN / Untouched: 14, 30, 50, 138, 144, 174, 176
Test III.	108VF & 176VF / 128V & 169F / 175VF & 109V / 135VF & 90V / 119VN / Untouched: 4, 20, 110, 155
Test IV.	176VF / 169F & 101V & 135VF & 128V / 109V & 119V / 90VN / 121VFN / Untouched: 145, 155
Test V.	176VF & 108V & 116F / 169F & 109V / 75V / 61VN / Untouched: 52, 110
Test VI.	117F & 72V & 9V & 7V & 181VF / 41F & 167VF & 56V / 22FN & 166FN & 122VN / 39FN & 38FN / Untouched: 11, 36, 46, 55, 106
Test VII.	176F / 9V / 117F / 169F & 181F / 167VF / 72VN & 41FN & 7VN & 166FN / Untouched: 22, 36, 39, 46, 56, 122
Test VIII.	108VF / 176VF & 9V / 131V & 32V / 7V / 166VN & 126VN / Untouched: 39, 43, 44
Test IX.	179F / 111V / 152F / 84VN / 67VN

B. Summary of Relative Preference Value of Frequently Tested Foods:

Impatiens capensis VF 3:0 / Solidago canadensis VF 5:1 / Sagittaria latifolia V 3:0 / Daucus Carota F 4:0 & Helianthus divaricatus F 5:0 / Oxalis stricta VF 3:0 & Cornus stolonifera V 3:1 & Rhamnus alnifolia V 5:0 / Vitis riparia V 2:1 & Typha latifolia V 2:1 / Parthenocissus quinquefolia V 1:3 / Eupatorium perfoliatum VF 0:3 / Scirpus atrovirens F 0:3

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

25. Amblycorypha rotundifolia
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	178F & 169F / 134F & 111V & 101VF & 141F & 117F / 174F & 113VF / 110V & 119V & 109V / 175VF / 146F / Untouched: 14, 16, 36, 47
Test II.	115F / 111V & 101VF & 109V & 110V & 178F / 176V & 117VF & 138F & 30V / 174FN & 119VN / Untouched: 14, 50, 144, 149
Test III.	108VF / 135VF & 128V & 169VF / 175VF & 176VF / 119V & 109VF / 119V & 109V / 90VN & 110VN / Untouched: 4, 20, 155
Test IV.	135F & 169VF & 101V / 128V & 119V & 109V / 176VF / 121VN / Untouched: 90, 145, 155
Test V.	108V / 169F / 75V & 110V & 116VF / 109VN & 176VN / Untouched: 52, 61
Test VI.	176VF / 147F & 169F / 113VF & 120V & 137F / 119V & 117F / 149VN / 179VN / Untouched: 12, 28, 64, 84
Test VII.	108VF / 169F & 176VF / 110V & 152F / 150F / Untouched: 79, 109, 161
Test VIII.	176VF / 110V / 111V & 84V / 51VN & 47VN / 119VN / Untouched: 74
Test IX.	179F / 111VN / 67VN / 84VN / Untouched: 159

B. Summary of Relative Preference Value of Frequently Tested Foods:

Impatiens capensis VF 3:0 / Helianthus divaricatus F 6:0 / Oxalis stricta VF 3:0 & Solidago canadensis VF 6:1 / Vitis riparia V 3:1 & Parthenocissus quinquefolia V 5:1 & Daucus Carota F 3:0 / Rhamnus alnifolia V 4:2 / Cornus stolonifera V 4:2 / Prunus serotina V 1:2

26. Scudderia c. curvicauda
(Tested middle August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	7V / 9V / 119V & 106V / 11F & 72V & 56V & 55V / 126F / 167FN & 36VN & 139VFN / 38FN & 34VN / Untouched: 22, 39, 46, 122, 130, 156, 166
Test II.	7V / 9V / 38V & 72V & 11F / 55V & 166VF / 176VN & 46VN & 36VN / Untouched: 34, 39, 41, 167
Test III.	7V & 9V / 117VF / 167VF & 11F / 55VN & 166FN / Untouched: 22, 34, 41, 46, 39
Test IV.	108VF / 116F / 136V & 109V / 82VF & 167F & 59V / 87F & 160V / 15VFN / 7VN/56VN / Untouched: 3, 35
Test V.	181F / 9V / 117F / 176VN & 41FN & 7VN / Untouched: 11, 22, 36, 38, 39, 46, 166, 167
Test VI.	108VF / 176F & 150F / 169F / 161FN & 109VN / 152FN / Untouched: 79, 110
Test VII.	108VF / 43V / 176F & 131VF / 160FN & 32VN / Untouched: 7, 9, 39, 44, 126, 166
Test VIII.	181F / 177F / 117F & 156VF / 130FN & 72VN / Untouched: 7, 9, 39, 46, 54, 56, 176
Test IX.	160F / 108V / 159F / 109VN & 59VN / 35VN / Untouched: 7, 15, 87
Test X.	9V / 117VF & 7V / 160F & 69VF / 108F / 176FN

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

B. Summary of Relative Preference Value of Frequently Tested Foods:

Sagittaria latifolia V 5:2 & Daucus Carota VF 4:0 & Impatiens capensis VF 5:0 / Typha latifolia V 4:5 / Solidago canadensis VF 2:4 & Agrostis alba F 3:1 / Eupatorium purpureum F 2:3 & Eupatorium perfoliatum VF 1:4 / Juncus Torreyi V 0:5

27. Scudderia septentrionalis
(Tested middle July)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	174F / 111VN & 176VN / 110VN & 109VN & 165FN / Untouched: 31, 50, 63, 79, 84, 86, 122, 134, 159, 175
Test II.	4V / 107V / 77VN / 174FN & 84VN / Untouched: 28, 31, 57, 63, 86, 90, 134, 159

28. Neoconocephalus ensiger
(Tested early August to early September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	27VF / 17F & 16F / 29F / Untouched: 49, 98, 103, 117, 135, 144, 148, 149, 165, 174
Test II.	12VF / 30F / 28F / 16F & 14F / Untouched: 98, 99, 101, 103, 117, 142, 144, 148, 149, 182, 183
Test III.	12F / 30F & 19F / 28F & 14F / 16FN
Test IV.	12F & 29F / 28F / Untouched: 1, 7
Test V.	12F / 18F / 29F & 28F & 19F / 30FN & 20FN
Test VI.	12F / 29F / 28FN / 20FN
Test VII.	11F / 22F/ 38F / 41FN & 39FN & 29FN / Untouched: 7, 34, 36, 46, 166, 167
Test VIII.	11F / 39F / 41F & 38F / 22F / 167FN / Untouched: 7, 9, 36, 46, 117, 166, 176, 181
Test IX.	21F & 12F / 30F / 29F & 28F / Untouched: 48, 117, 144, 179
Test X.	26F / 15F / Untouched: 7, 35, 59, 82, 87, 108, 109, 159, 160
Test XI.	30F / 111F (fruit) / 18F / 86FN (fruit) / Untouched: 80, 146

B. Summary of Relative Preference Value of Frequently Tested Foods:

Andropogon Gerardi F 6:0 / Setaria glauca F 4:1 & Poa pratensis F 5:1 / Poa compressa F 5:1

29. Conocephalus f. fasciatus
(Tested early August to middle September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	11F / 41F / 27V / 130V & 22V / 154V & 38F / Untouched: 7, 9, 34, 36, 39, 45, 46, 72, 106, 122, 124, 132, 139, 166

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

Test II.	9V / 11F / 39F / 44VN & 38VFN / 22VN / Untouched: 7, 36, 45, 46, 72, 130, 139, 154, 167
Test III.	11F / 9VF & 181F / 139FN / 56VN & 36FN / Untouched: 34, 39, 46, 124, 126, 166, 167
Test IV.	11F / 124F & 46F / 167VN & 41FN / Untouched: 9, 39, 55, 56, 166
Test V.	11F / 9V & 41F / 38V & 167F / 166F / 7VN / 46VFN / 34VN & 39FN / Untouched: 36, 176
Test VI.	22F & 11F / 9V / 39F & 41F & 46F & 117F & 166VF / 7VN & 34VN & 167VN / Untouched: 55
Test VII.	22F / 166VF & 11F / 9V/38FN & 39FN & 167FN & 41FN / Untouched: 7, 34, 36, 46
Test VIII.	22F / 11F / 166F & 181F / 38VN & 41FN & 167FN & 117FN & 39FN / 9VN / 46VN & 7VN / Untouched: 36, 176
Test IX.	28F / 30F / 21F / 144VN & 117FN & 138FN / 142FN & 99FN & 93VN / Untouched: 12, 16, 48, 149, 179
Test X.	26F / 15F / Untouched: 7, 35, 59, 82, 87, 108, 109, 159, 160

B. Summary of Relative Preference Value of Frequently Tested Foods:

Agrostis alba F 8:0 & Leersia oryzoides VF 4:1 / Scirpus validus F 3:3 & Sagittaria latifolia V 5:3 & Eupatorium perfoliatum VF 4:3 / Eleocharis calva VF 2:3 / Scirpus atrovirens F 2:6 & Eupatorium purpureum VF 1:6 & Juncus Torreyi VF 2:5 / Typha latifolia V 0:7 & Carex retrorsa V 0:5 & Carex vulpinoidea F 0:6

30. Orchelimum gladiator
(Tested middle July to middle August)

A. Tabular Synopsis of Differential Feeding Tests:

Test I.	11F / 9V / 38F & 46V / 166FN & 130VN & 22VN / Untouched: 7, 34, 36, 39, 41, 56, 98, 106, 122, 124, 154
Test II.	9V & 10F & 38F & 11F / 39VN & 121VN / 132FN / 130VN & 46FN / Untouched: 7, 34, 36, 41, 45, 96, 98, 116, 124, 154
Test III.	9V & 11F / 38F / 39VN & 121VN / 132VN & 98VN & 96FN & 34VN / Untouched: 1, 7, 27, 36, 45, 46, 72, 126
Test IV.	9V & 11F / 154V & 139F & 130V / 34VN & 1VN / 38FN & 46VN / 22VN / Untouched: 36, 39, 45, 71, 124
Test V.	9VF / 8V & 11F / 181F & 36V & 139F / 154VN & 38FN / Untouched: 34, 39, 45, 46, 166
Test VI.	11F / 41F / 38F / 9VN & 181FN / 132VN / Untouched: 36, 39, 46, 45, 117, 126, 130, 139
Test VII.	9V / 72V & 11F / 38VFN & 44FN & 167VN / Untouched: 7, 22, 36, 39, 45, 46, 130, 139, 154
Test VIII.	9V / 11F / 124F / 166F & 167F / 56VN & 39FN / Untouched: 41, 46, 55
Test IX.	11F / 41F / 166VF & 9V & 167F / 38FN / 176VN & 34VN / Untouched: 7, 36, 39, 46
Test X.	9V / 41F & 11F / 22F / 117F & 166F / Untouched: 7, 34, 36, 39, 46, 55, 167

B. Summary of Relative Preference Value of Frequently Tested Foods:

Sagittaria latifolia V 9:1 & Agrostis alba F 10:0 / Eleocharis calva F 4:4 / Lycopus americanus V 1:4 / Aster lateriflorus V 1:4 / Carex retrorsa V 0:7 & Scirpus atrovirens VF 0:10 & Carex vulpinoidea V 1:8

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

31. Orchelimum nigripes
(Tested late September)

A. Tabular Synopsis of Differential Feeding Tests:

Test I. 22F / 9V / 42F & 32F / 7FN / Untouched: 56, 119
Test II. 22F / 9F / 32VN / Untouched: 7, 42, 56, 119

32. Oecanthus nigricornis quadripunctatus
(Tested middle September to middle October)

A. Tabular Synopsis of Differential Feeding Tests:

Test I. 179F / 176F / 138F / Untouched: 1, 10, 28, 84, 86, 93, 102, 111, 134, 168, 178
Test II. 179F / 153F / 176F / 157FN / Untouched: 1, 16, 28, 93, 148, 168, 178
Test III. 153F / 138F / 159F & 175F / Untouched: 16, 17, 21, 33, 48, 81, 94, 109, 114, 117, 144, 148
Test IV. 153F / 138F & 157F / 117F & 179F / Untouched: 1, 10, 28, 111, 148, 178, 180
Test V. 175F / 153F / 138F / 159FN / Untouched: 156, 174
Test VI. 157F / 138F & 156F & 154F / Untouched: 117, 153, 164
Test VII. 156F / 99F / 153F & 159F / 117F & 148F
Test VIII. 156F / 154FN / 176FN

B. Summary of Relative Preference Value of Frequently Tested Foods:

Aster novae-anglieae F 3:1 / Aster laevis F 5:1 / Linaria vulgaris F 5:0 / Daucus Carota F 2:2 / Achillea Millefolium F 1:3

[18] Formulation and use of data obtained during the differential feeding tests:

The data obtained from the differential feeding tests are presented individually in Table II, which includes, for each species of Orthoptera, a Tabular Synopsis of Differential Feeding Tests and a Summary of Relative Preference Value of Frequently Tested Foods.

The Tabular Synopsis of Differential Feeding Tests, Table IIA, shows the relative amount of feeding by individuals of a species of Orthoptera on different food-plants during each of several tests. The foods are arranged in categories of decreasing acceptance separated from one another by the symbol /. Two or more plants in the same category have equal preference ratings. Certain letters (V, F, N) are listed with the code numbers representative of the food-plants. The symbol V denotes eating of vegetative parts of a plant, including leaves and stems; F that of floral or reproductive parts, including flowers and fruits; and N denotes nibbling, which is here defined as feeding for a period so short as to result in negligible

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

damage to the food. Where nibbling is not specified, eating is implied. The seasonal period during which testing occurred appears under each feeder's name; this latter is important in disclosing the seasonal condition of the food-plants at the time of feeding. The reader will note that code numbers have been substituted for the names of plant species. While it would be desirable to write out the name of each plant every time it is used, it has been necessary to make this compromise between clarity and economy; thus, the identity of the food-plants must be obtained by reference to Appendix C, Plants Used in Study.

The Summary of Relative Preference Value of Frequently Tested Foods, Table IIB, shows the relative preference value of each species of food-plant tested often enough to give dependable results, and it also includes notations concerning the food parts usually selected. Its formulation is fairly simple. The Tabular Synopsis of a given species of Orthoptera is first examined to discover the identity of all frequently tested plants; such plants are usually those tested five or more times. The relative preference value of each food is then determined graphically.

Let us suppose that there are the following preferences in three tests: Test I. 9 / 3 / 15 & 8; Test II. 9 / 3 / 15 / 8; Test III. 9 / 15 / 3 / 8. Each time a food-plant is preferred over another it receives a point; each time plants are equally preferred, each receives a point. If plant 9 (*Sagittaria latifolia*, as shown by examination of Appendix C) is plotted in this manner against the other three plants, the result of Test I is as shown in Text Fig. 1, below:

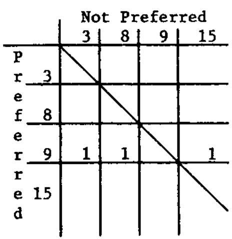


Fig. 1

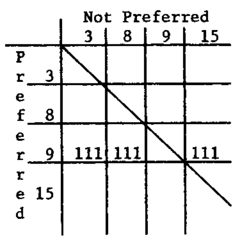


Fig. 2

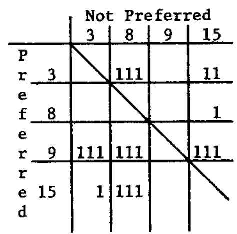


Fig. 3

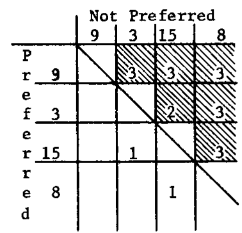


Fig. 4

TABLE II (CONT.)
RESULTS OF DIFFERENTIAL FEEDING TESTS

If plant 9 is plotted against the other three plants in all three tests, the graph will appear as in Text Fig. 2, above. When all four plants have been plotted against one another in the three tests, the graph will appear as in Text Fig. 3, above. By comparison of numbers, the preferred plants may then be selected and shaded to make them stand out on the graph. After a rearrangement of the plants in order of preference, the graph will appear as in Text Fig. 4, above.

It is apparent, on examination of Text Fig. 4, that 9 / 3 / 15 / 8, which is the basic information found in the Summary of Relative Preference Value of Frequently Tested Foods. The above graphs used in the formulation of the Summary are not essential to its presentation and, therefore, have been omitted.

The Summary of Relative Preference Value of Frequently Tested Foods also includes notations concerning parts of plants selected for feeding, whether vegetative or floral, and the acceptance-rejection ratio. The latter, which is a comparison of the frequency of eating as opposed to that of nibbling and complete rejection, usually shows a high degree of correlation with the preference values of food-plants; as preference decreases, rejections and nibbling tend to increase, and vice versa. In general, it was found that, whenever the acceptance-rejection ratio is 2:1 or greater, the food is relatively attractive to the feeder; whenever the ratio is 1:1 or less, the food is relatively unattractive.

Because of this close correlation the acceptance-rejection ratio may often be used in estimating the relative attractiveness of foods. Plants equally acceptable on the basis of scattered feeding experiments often can be ranked more accurately using the ratio. For example, a plant having an acceptance-rejection ratio of 13:5, but tied with one having a ratio of 2:7, is probably preferred. The former ratio indicates consistent and the latter inconsistent acceptance.

Plants not listed in the Summary of Relative Preference Value of Frequently Tested Foods because they were insufficiently tested can also be ranked, though grossly, if they have been tested one or more times. This is accomplished by comparison of their relative attractiveness with that of one or more plants listed in the Summary. Let us say that, on the basis of three tests with a species of Orthoptera, we find that 9 / 3 / 15 / 8, and that the results of a fourth test are as follows: Test IV. 9 / 3 / 21 / 8.

On the basis of incomplete data, we can assume that plant 21 belongs near 15 in its preference value, for, like 15, it is less acceptable than plants 9 and 3 but more acceptable than 8. Its exact preference value cannot be determined, of course, without further testing.

TABLE III[23]

Classification and Distribution of Structural Adaptations of Mouthparts of Orthoptera — Groups and Species / Mouthpart Adaptations	Carnivorous	Forbivorous-seminivorous-carnivorous	Seminivorous	Modified Omnivorous	Omnivorous	Omnivorous toward forbivorous	Dendrophagous	Forbivorous toward dendrophagous	Forbivorous	Forbivorous toward herbivorous	Herbivorous toward forbivorous	Herbivorous	Herbivorous toward graminivorous	Graminivorous toward herbivorous	Graminivorous
Dermaptera:															
Doru a. aculeatum					X										
Blattidae:															
Blatta orientalis					X										
Blattella germanica					X										
Parcoblatta uhleriana					X										
Parcoblatta virginica					X										
Mantidae:															
Tenodera aridifolia sinensis	X														
Phasmidae:															
Diapheromera femorata							X								
Acridinae:															
Chloealtis conspersa															X
Chorthippus longicornis															X
Orphulella speciosa															X
Pseudopomala brachyptera															X
Syrbula admirabilis															X
Oedipodinae:															
Arphia p. pseudonietana															X
Arphia sulphurea															X
Camnula pellucida												X			
Chortophaga viridifasciata												X			
Dissosteira carolina															X

[23] Based largely on mandibular form. See pp. 79 - 81 for a brief discussion of the following structural adaptations.

TABLE III (CONT.)

Classification and Distribution of Structural Adaptations of Mouthparts of Orthoptera / Groups and Species	Carnivorous	Forbivorous-seminivorous-carnivorous	Seminivorous	Modified Omnivorous	Omnivorous	Omnivorous toward forbivorous	Dendrophagous	Forbivorous toward dendrophagous	Forbivorous	Forbivorous toward herbivorous	Herbivorous toward forbivorous	Herbivorous	Herbivorous toward graminivorous	Graminivorous toward herbivorous	Graminivorous
Oedipodinae, cont.:															
Encoptolophus s. sordidus															X
Pardalophora apiculata												X			
Pardalophora haldemanii												X			
Spharagemon b. bolli												X			
Spharagemon collare												X			
Cyrtacanthacridinae:															
Appalachia arcana									X						
Dendrotettix quercus												X			
Leptysma marginicollis															X
Melanoplus angustipennis									X						
Melanoplus b. bilituratus											X				
Melanoplus bivittatus												X			
Melanoplus confusus												X			
Melanoplus f.-r. femur-rubrum									X						
Melanoplus keeleri luridus									X						
Melanoplus p. punctulatus									X						
Melanoplus s. scudderi											X				
Paroxya hoosieri										X					
Phoetaliotes nebrascensis													X		
Schistocerca lineata											X				
Zubovskya g. canadensis										X					
Tetrigidae:															
Tetrix ornata					X										
Tetrix subulata					X										
Tettigidea l. lateralis					X										

TABLE III (CONT.)

Classification and Distribution of Structural Adaptations of Mouthparts of Orthoptera

Groups and Species / Mouthpart Adaptations	Carnivorous	Forbivorous-seminivorous-carnivorous	Seminivorous	Modified Omnivorous	Omnivorous	Omnivorous toward forbivorous	Dendrophagous	Forbivorous toward dendrophagous	Forbivorous	Forbivorous toward herbivorous	Herbivorous toward forbivorous	Herbivorous	Herbivorous toward graminivorous	Graminivorous toward herbivorous	Graminivorous
Rhaphidophorinae:															
Ceuthophilus brevipes				X											
Ceuthophilus meridionalis				X											
Ceuthophilus thomasi				X											
Ceuthophilus uhleri				X											
Phaneropterinae:															
Amblycorypha oblongifolia									X						
Amblycorypha rotundifolia									X						
Scudderia c. curvicauda									X						
Scudderia f. furcata									X						
Scudderia septentrionalis									X						
Copiphorinae:															
Neoconocephalus ensiger			X												
Conocephalinae:															
Conocephalus attenuatus		X													
Conocephalus brevipennis		X													
Conocephalus f. fasciatus		X													
Conocephalus nigropleurum		X													
Conocephalus strictus		X													
Orchelimum gladiator		X													
Orchelimum nigripes		X													
Orchelimum volantum		X													
Orchelimum vulgare		X													
Decticinae:															
Atlanticus testaceus	X														

TABLE III (CONT.)

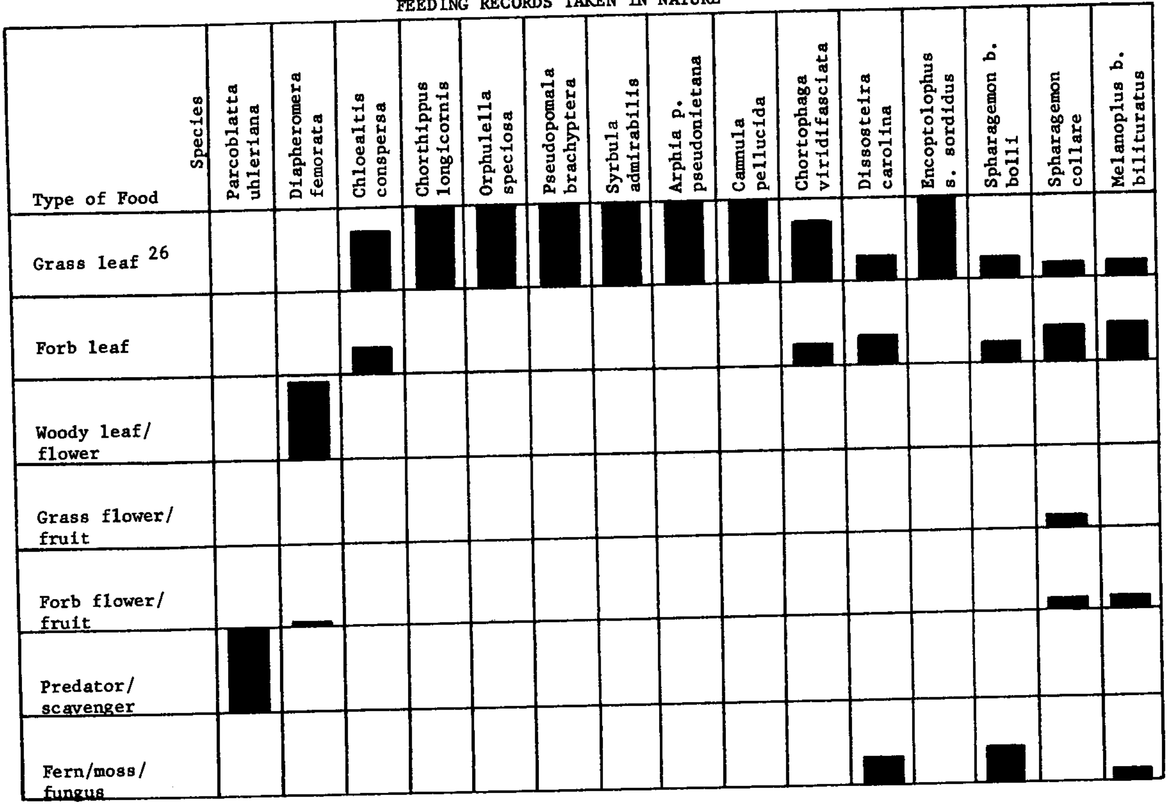
Classification and Distribution of Structural Adaptations of Mouthparts of Orthoptera / Groups and Species	Carnivorous	Forbivorous-seminivorous-carnivorous	Seminivorous	Modified Omnivorous	Omnivorous	Omnivorous toward forbivorous	Dendrophagous	Forbivorous toward dendrophagous	Forbivorous	Forbivorous toward herbivorous	Herbivorous toward forbivorous	Herbivorous	Herbivorous toward graminivorous	Graminivorous toward herbivorous	Graminivorous
Gryllinae: Acheta pennsylvanicus						X									
Nemobiinae: Nemobius allardi						X									
Oecanthinae: Oecanthus angustipennis				X											
Gryllotalpidae: Gryllotalpa hexadactyla				X											

TABLE IV[24]
SUMMARY OF PRIMARY AND SECONDARY FOOD-HABITS OF ORTHOPTERA, BASED ON PRESENT STUDIES SUPPLEMENTED BY LITERATURE

Groups	Primary Food-Habits	Secondary Food-Habits
Dermaptera	Omnivorous or omnivorous-carnivorous	
Blattidae	Omnivorous	
Mantidae	Carnivorous	
Phasmidae	Dendrophagous	
Acridinae	Graminivorous	
Oedipodinae	Graminivorous	Forbivorous
Cyrtacanthacridinae	Forbivorous or forbivorous-graminivorous	Dendrophagous
Tetrigidae	Omnivorous-herbivorous	
Rhaphidophorinae	Omnivorous or omnivorous-carnivorous	
Phaneropterinae	Forbivorous	Dendrophagous
Copiphorinae	Seminivorous	
Conocephalinae	Forbivorous-seminivorous-carnivorous	
Decticinae	Omnivorous-carnivorous	
Gryllinae & Nemobiinae	Omnivorous or omnivorous-herbivorous	Carnivorous
Oecanthinae	Forbivorous-carnivorous	Dendrophagous
Gryllotalpidae	Omnivorous	Carnivorous

[24] Based on the discussion presented on pp.81-113. It summarizes the author's impressions of food selection in a majority of the species of each of the following groups and ignores variations of food-habit which may occur in certain species.

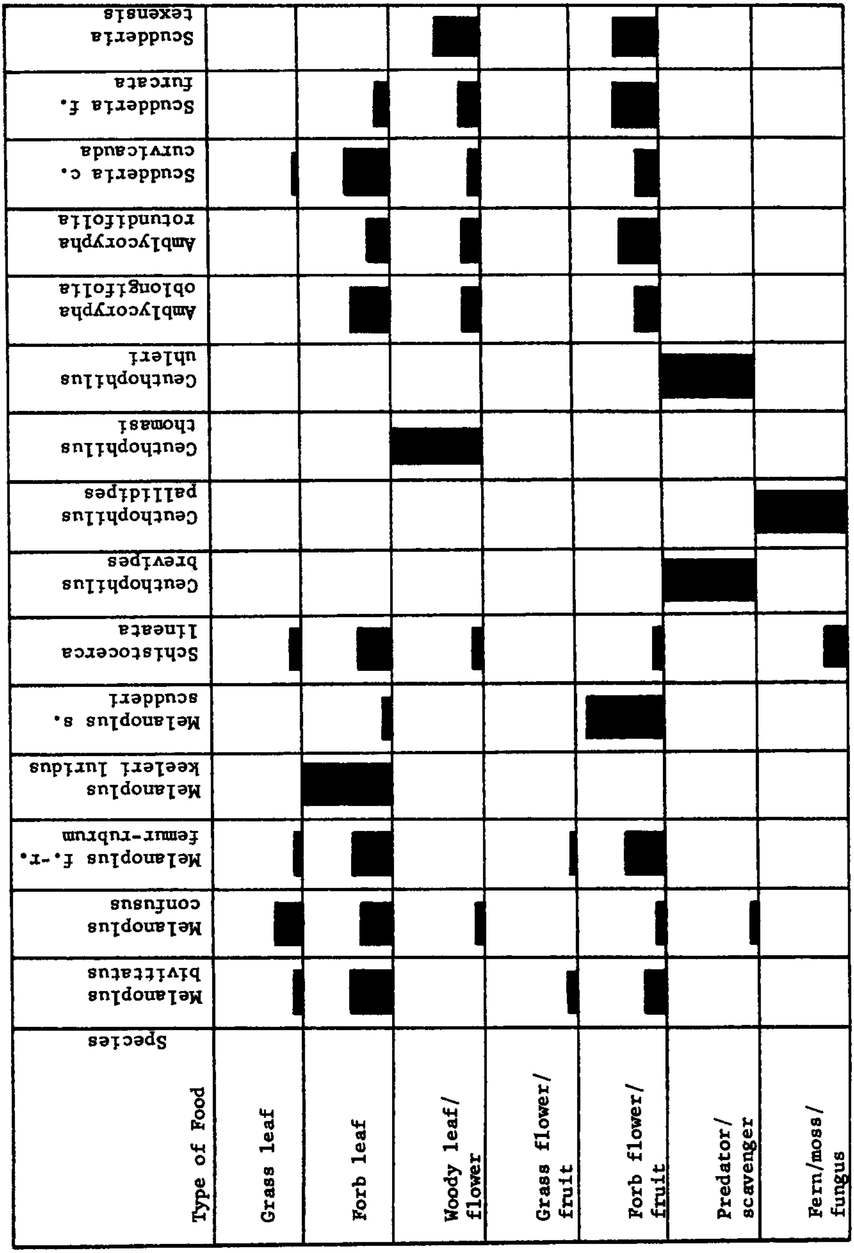
GRAPH I [25]
FEEDING RECORDS TAKEN IN NATURE



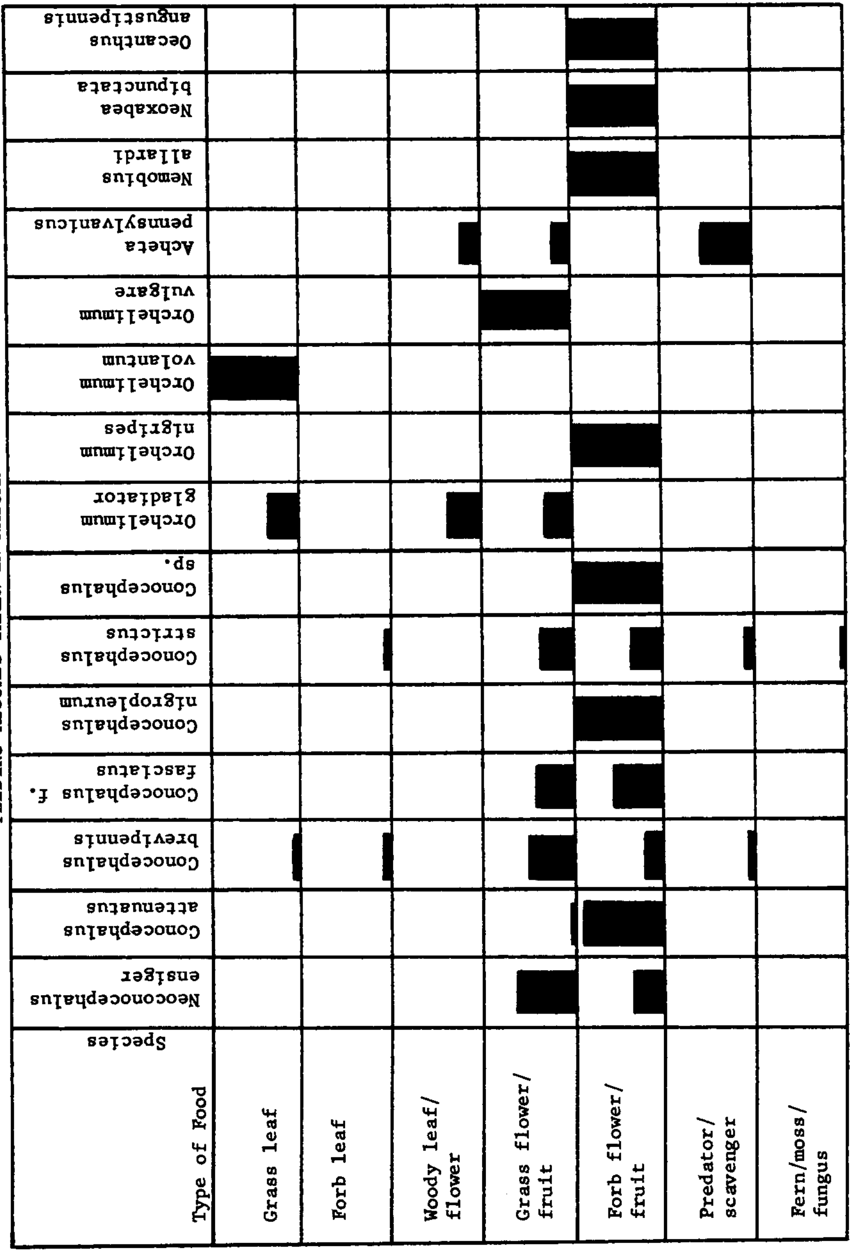
25 The feeding records obtained during this study and presented in their entirety in Table I are here reworked on the basis of food categories. The height of each bar corresponds to the percentage of feeding observed in that given category; thus, examination of the graph shows that Chortophaga was found eating grass leaves 75% of the time, the remainder of the time feeding on forb leaves.

26 The term grass, as loosely used here, refers to plants of the Gramineae, Cyperaceae, and Juncaceae.

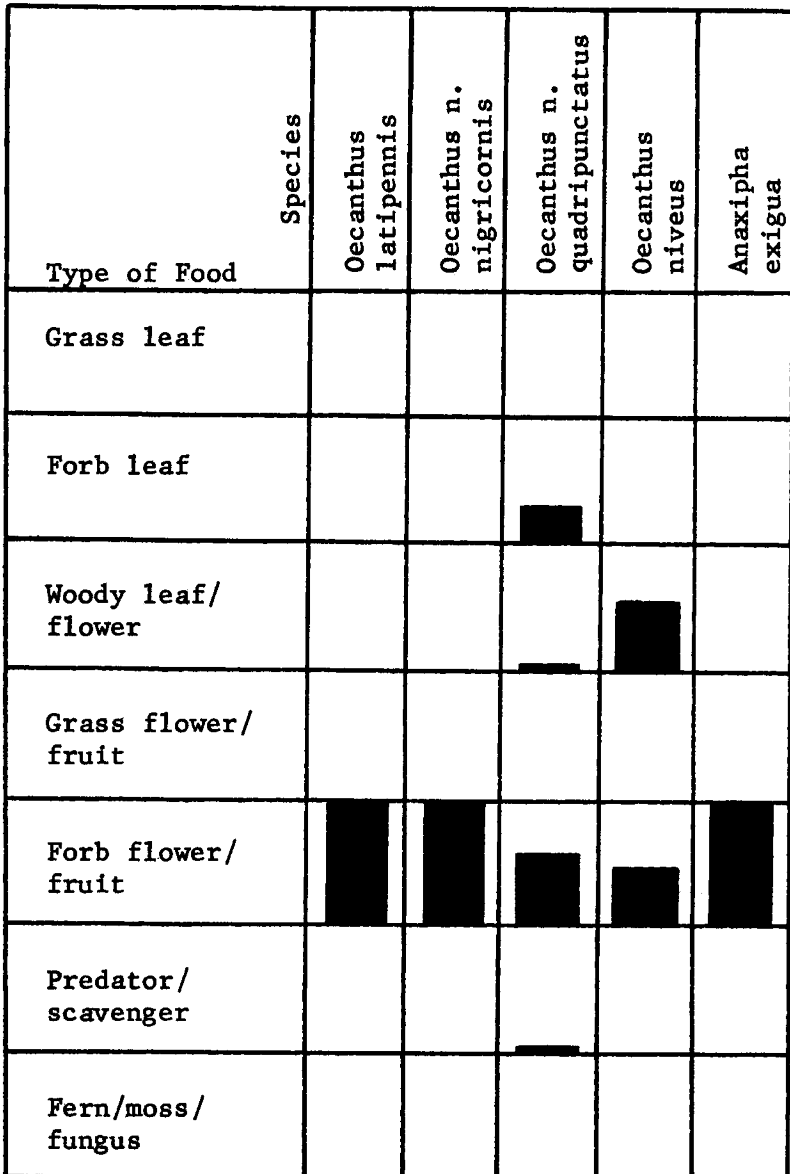
GRAPH I (CONT.)
FEEDING RECORDS TAKEN IN NATURE



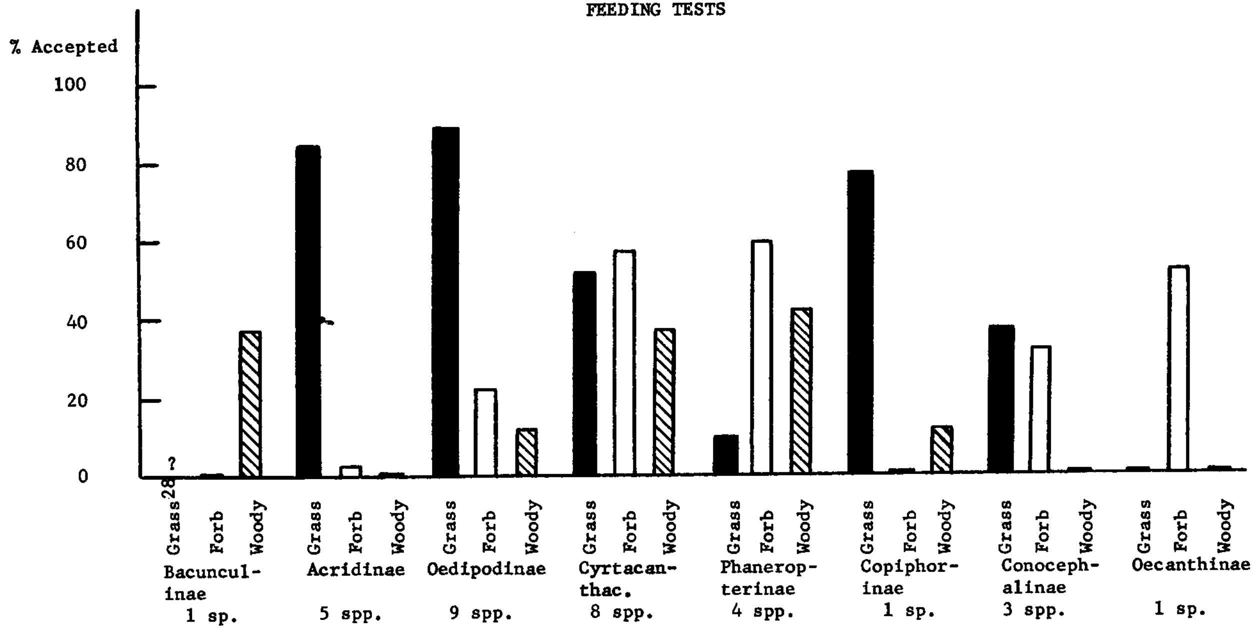
GRAPH I (CONT.)
FEEDING RECORDS TAKEN IN NATURE



GRAPH I (CONT.)
FEEDING RECORDS TAKEN IN NATURE



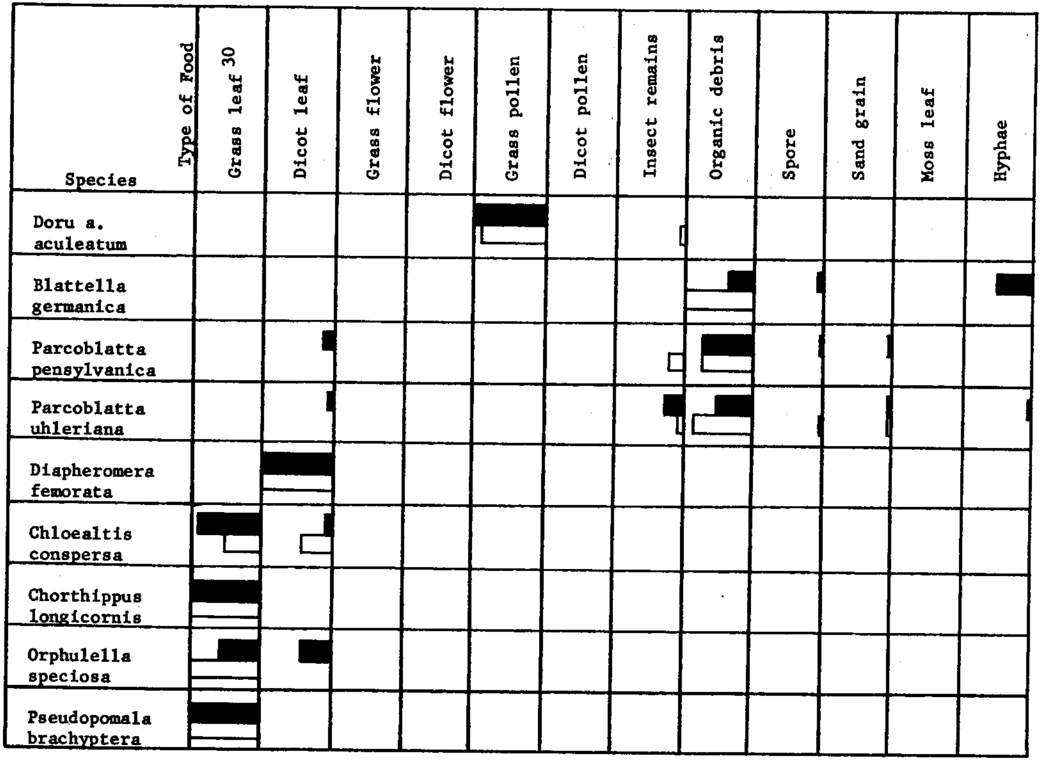
GRAPH II [27]
RELATIVE ACCEPTANCE OF FOODS BY SUBFAMILIES OF ORTHOPTERA DURING DIFFERENTIAL FEEDING TESTS



[27] Graph II shows the relative acceptance of plants belonging to woody, forb, and grass categories by species of Orthoptera grouped taxonomically. The following steps are involved in its formulation: for grasses, the number of acceptances and that of rejections and nibbling during the differential feeding tests is counted for a given species of feeder, and this information is used to calculate the percentage of acceptance of grasses by this orthopteran. The percentage of acceptance of grasses is then determined in the same manner for the remainder of the species of this subfamily of Orthoptera, and these percentages are averaged to yield a mean percentage of acceptance of grasses for the subfamily. This procedure is repeated to determine the percentage of acceptance of forbs and then of woody plants. The remaining subfamilies are then treated in the same manner. The cross-hatched bars denote acceptance of woody plants, the solid bars that of grasses, and the empty bars that of forbs. The height of each bar indicates the percentage of acceptance. The number of species tested appears below each subfamily name.

[28] The term grass, as loosely used here, refers to plants of the Gramineae, Cyperaceae, and Juncaceae.

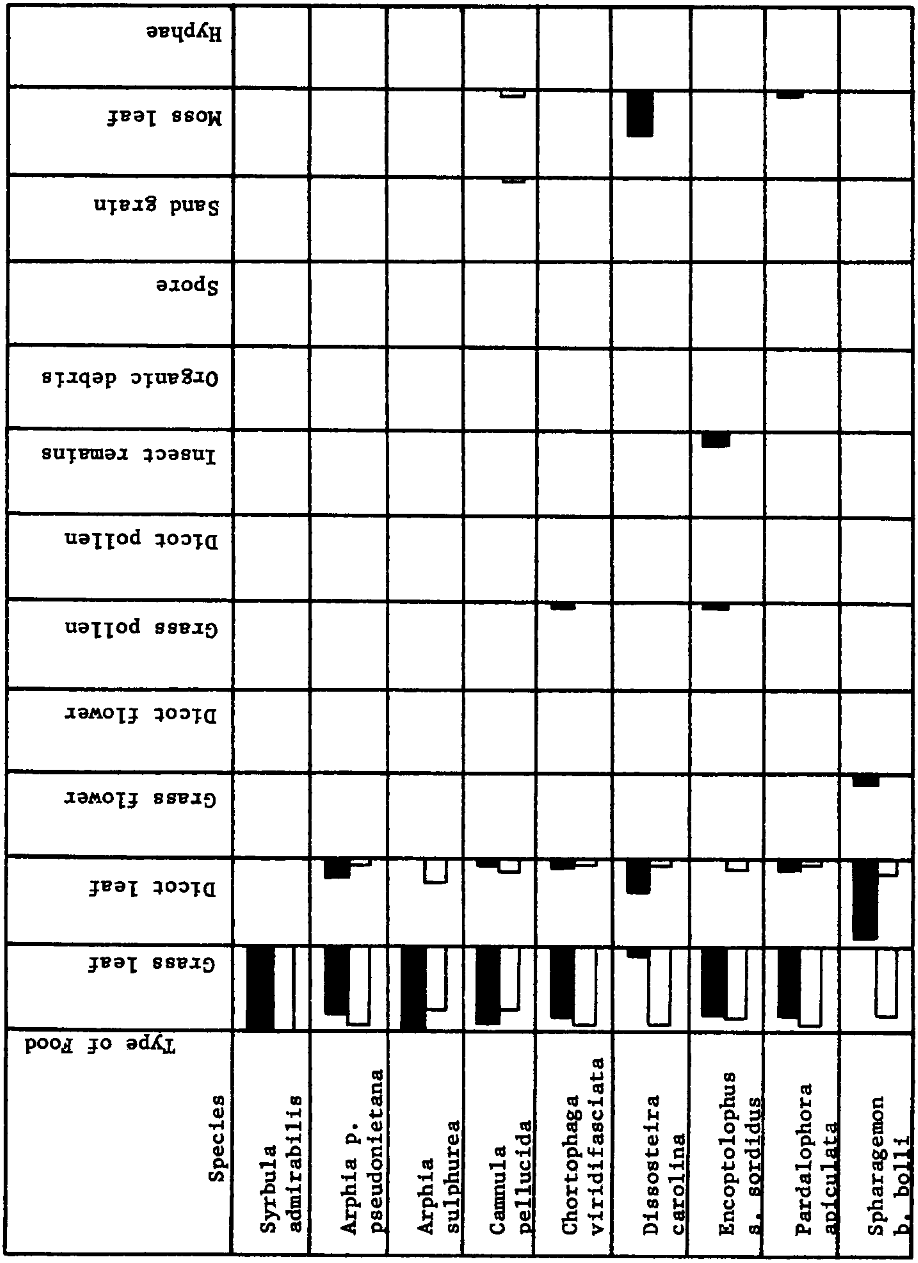
GRAPH III [29]
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS



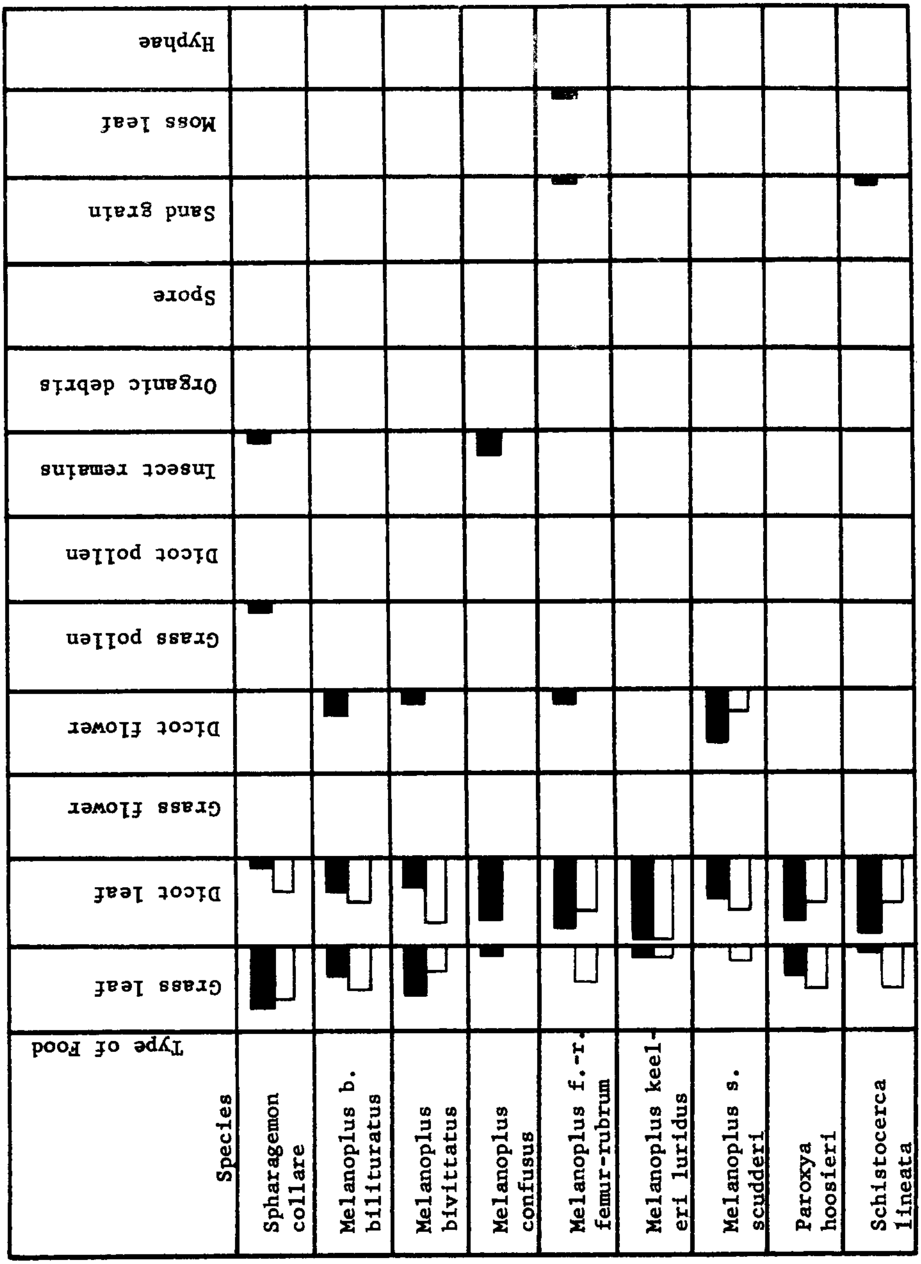
29 The composition of the crop contents and fecal materials of Orthoptera examined during this study is summarized in Graph III. A solid bar denotes data from crop analyses and an empty bar that from fecal analyses. The height of each bar shows the estimated percentage of the content belonging in a given food category; for example, 100% of both the crop contents and the fecal materials of Diapheromera femorata were of dicot leaf origin. See pp.79 - 80 for a brief discussion of the techniques of analysis.

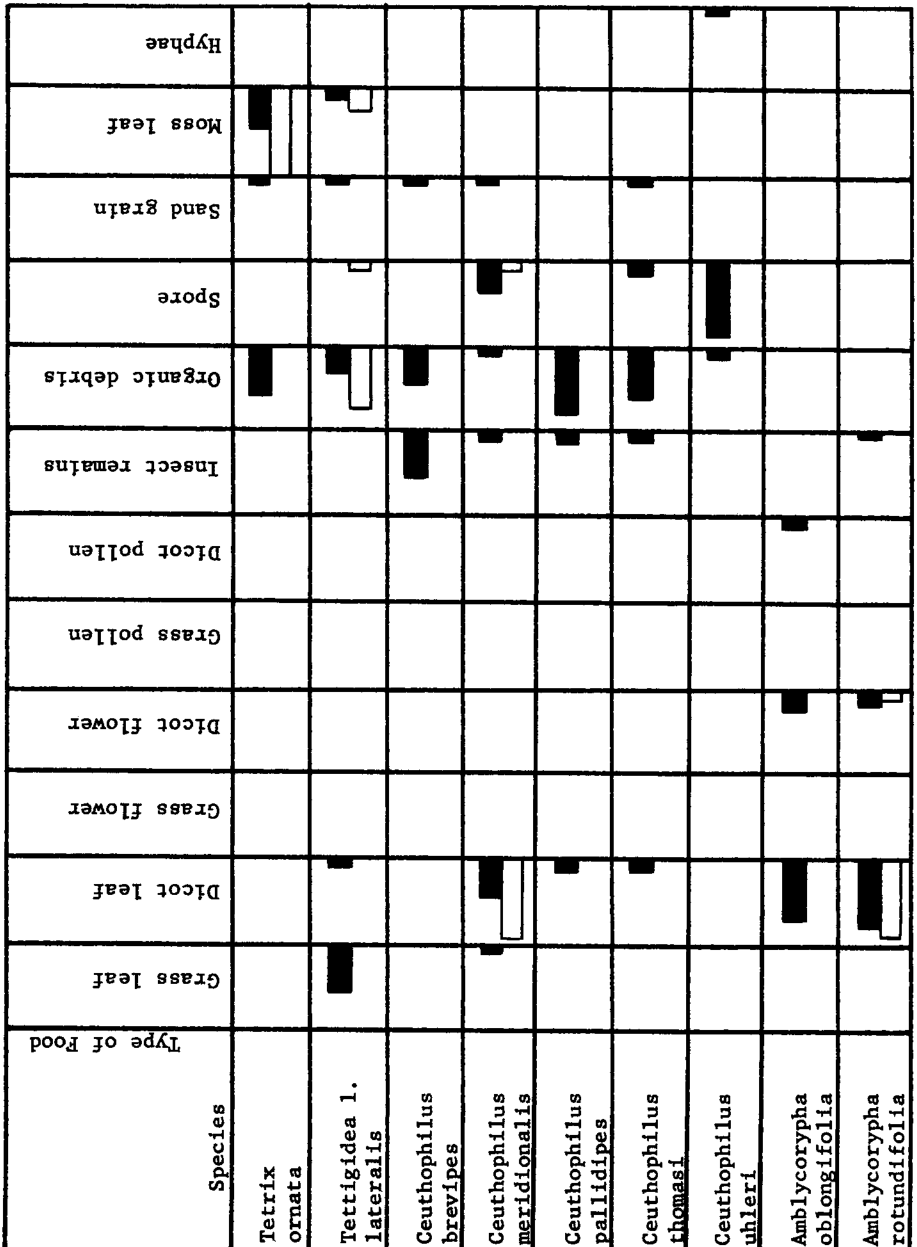
30 The term grass, as loosely used here, refers to plants of the Gramineae, Cyperaceae, and Juncaceae.

GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS

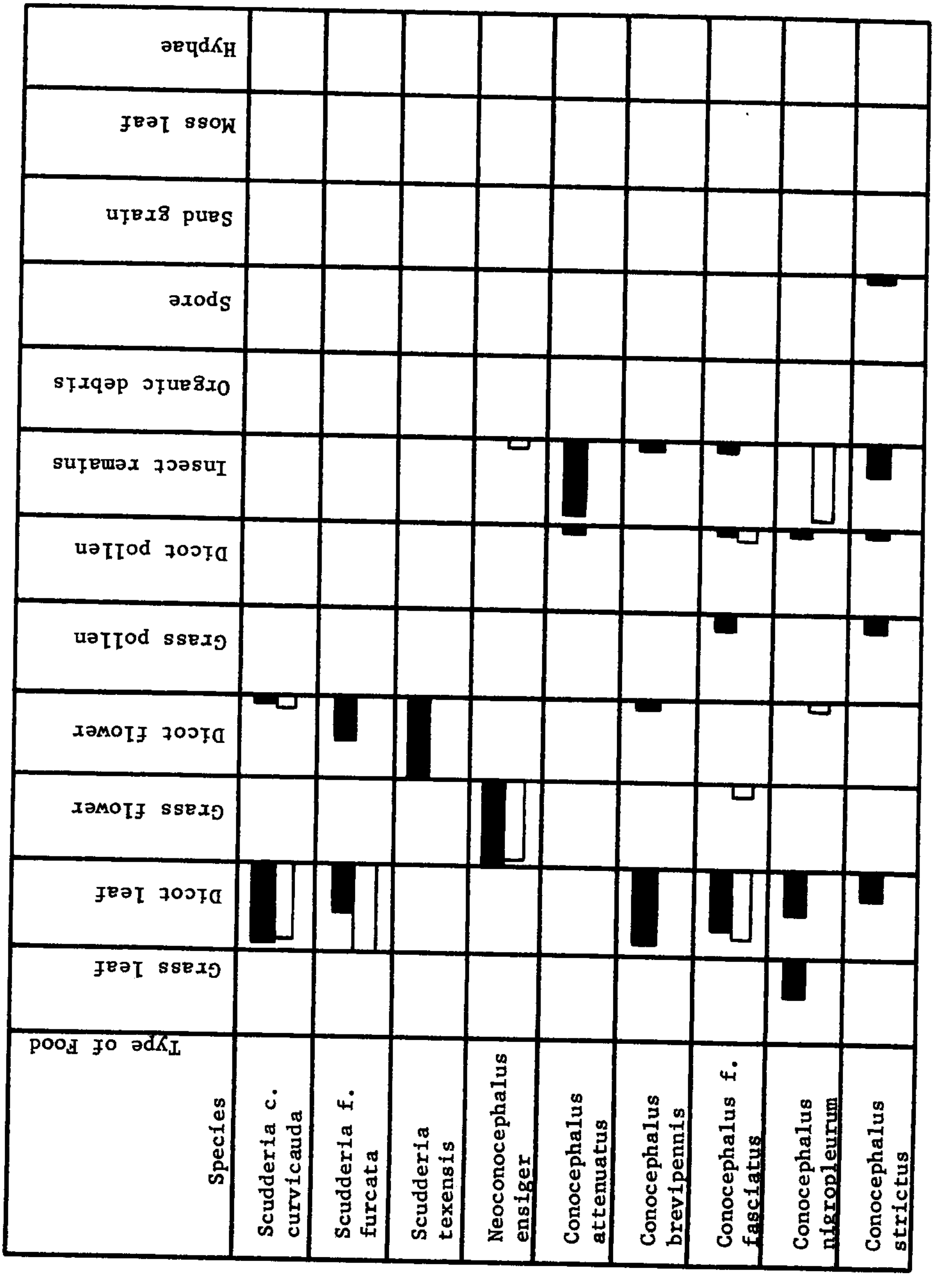


GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS



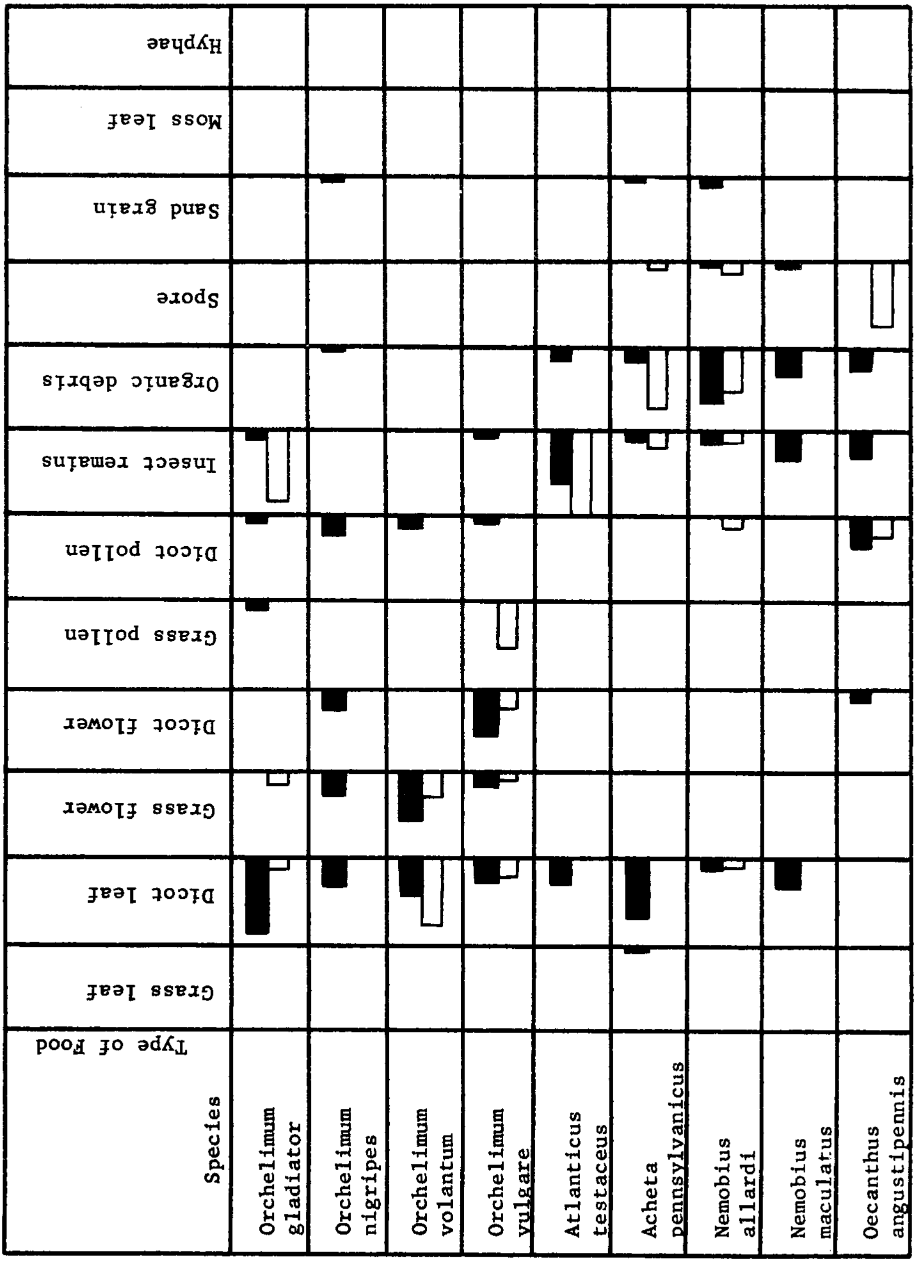


GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS

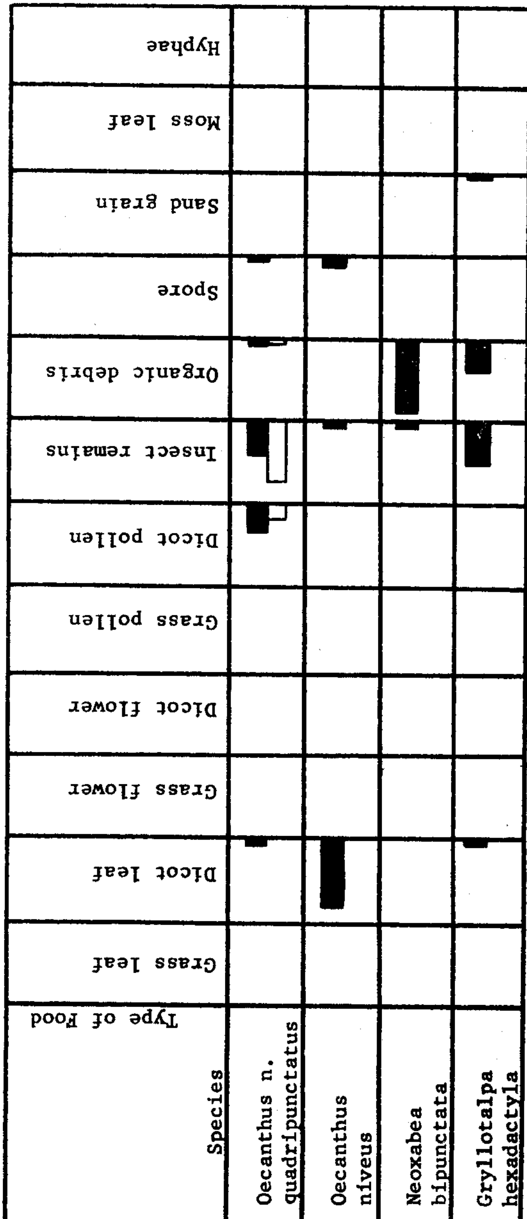


GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS AND FECAL MATERIALS

GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS



GRAPH III (CONT.)
RESULTS OF ANALYSES OF CROP CONTENTS
AND FECAL MATERIALS



APPENDIX A

GROUPS AND SPECIES OF ORTHOPTERA STUDIED

The preceding report deals with food selection in seventy-six species and subspecies of Orthoptera[31] occurring in Michigan—about one-half of the total number known from the entire state. Among these are representatives of every suborder and family found in Michigan, as well as most of the families occurring in the United States. Except at the onset of the investigation, when Dr. T. H. Hubbell kindly assisted in the determination of certain difficult specimens, the author made all determinations by reference to standard works and comparison with identified material in the collections of the University of Michigan Museum of Zoology. The species studied and their current classification are shown in the following list:

Order DERMAPTERA (earwigs)

Forficulidae (earwigs)
    Forficulinae
        Doru a. aculeatum (Scudder)

Superorder ORTHOPTEROIDEA
("*ORTHOPTERA*" sens. lat.)
Order OÖTHECARIA

Blattidae sens. lat. or Blattodea (cockroaches)
    Pseudomopinae
        Blattella germanica (Linnaeus)
        Parcoblatta pensylvanica (DeGeer)
        Parcoblatta uhleriana (Saussure)
        Parcoblatta virginica (Brunner)
    Blattinae
        Blatta orientalis Linnaeus
    Blaberinae
        Byrsotria fumigata (Guerin)[32]
Mantidae sens. lat. or Mantodea (praying mantids)
    Mantinae
        Tenodera aridifolia sinensis Saussure

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[31] The term Orthoptera, which is here used loosely, includes insects belonging to the orders Orthoptera and Dermaptera, both of which are customarily studied by orthopterists.
[32] Not a native species.

ORDER PHASMIDA OR PHASMODEA (WALKING-STICKS)

PHASMIDAE SENS. LAT. OR PHASMIDA
BACUNCULINAE
Diapheromera femorata (Say)

ORDER SALTATORIA

SUBORDER COELIFERA

SUPERFAMILY ACRIDOIDEA

ACRIDIDAE (SHORT-HORNED GRASSHOPPERS)
ACRIDINAE (SLANT-FACED LOCUSTS)
Chloealtis conspersa Harris
Chorthippus longicornis (Latreille)
Orphulella speciosa (Scudder)
Pseudopomala brachyptera (Scudder)
Syrbula admirabilis (Uhler)
OEDIPODINAE (BAND-WINGED LOCUSTS) [33]
Arphia p. pseudonietana (Thomas)
Arphia sulphurea (Fabricius)
Camnula pellucida (Scudder)
Chortophaga viridifasciata (DeGeer)
Dissosteira carolina (Linnaeus)
Encoptolophus s. sordidus (Burmeister)
Pardalophora apiculata (Harris)
Pardalophora haldemanii (Scudder)
Spharagemon b. bolli Scudder
Spharagemon collare (Scudder)
CYRTACANTHACRIDINAE (SPINE-BREASTED LOCUSTS)
Appalachia arcana Hubbell and Cantrall
Dendrotettix quercus Packard
Leptysma marginicollis (Serville)
Melanoplus a. angustipennis (Dodge)
Melanoplus b. bilituratus (F. Walker)
Melanoplus bivittatus (Say)
Melanoplus confusus Scudder
Melanoplus f.-r. femur-rubrum (DeGeer)
Melanoplus keeleri luridus (Dodge)
Melanoplus p. punctulatus (Scudder)
Melanoplus s. scudderi (Uhler)
Paroxya hoosieri (Blatchley)
Phoetaliotes nebrascensis (Thomas)
Schistocerca lineata Scudder
Zubovskya glacialis canadensis (E. M. Walker)

[33] See footnote 9.

TETRIGIDAE (GROUSE LOCUSTS)
- *Tetrix ornata* (Say)
- *Tetrix subulata* (Linnaeus)
- *Tettigidea l. lateralis* (Say)

SUBORDER ENSIFERA

SUPERFAMILY TETTIGONOIDEA

GRYLLACRIDIDAE

RHAPHIDOPHORINAE (CAVE AND CAMEL CRICKETS)
- *Ceuthophilus brevipes* Scudder
- *Ceuthophilus meridionalis* Scudder
- *Ceuthophilus pallidipes* Walker
- *Ceuthophilus thomasi* Hubbell
- *Ceuthophilus uhleri* Scudder

TETTIGONIIDAE

PHANEROPTERINAE (BUSH AND ROUND-HEADED KATYDIDS)
- *Amblycorypha oblongifolia* (DeGeer)
- *Amblycorypha rotundifolia* (Scudder)
- *Scudderia c. curvicauda* (DeGeer)
- *Scudderia f. furcata* Brunner
- *Scudderia septentrionalis* (Serville)
- *Scudderia texensis* Saussure and Pictet

COPIPHORINAE
- *Neoconocephalus ensiger* (Harris)

CONOCEPHALINAE (MEADOW GRASSHOPPERS)
- *Conocephalus attenuatus* (Scudder)
- *Conocephalus brevipennis* (Scudder)
- *Conocephalus f. fasciatus* (DeGeer)
- *Conocephalus nigropleurum* (Bruner)
- *Conocephalus strictus* (Scudder)
- *Orchelimum gladiator* (Bruner)
- *Orchelimum nigripes* (Scudder)
- *Orchelimum volantum* McNeill
- *Orchelimum vulgare* Harris

DECTICINAE (SHIELD-BEARERS)
- *Atlanticus testaceus* (Scudder)

SUPERFAMILY GRYLLOIDEA

GRYLLIDAE

GRYLLINAE (FIELD CRICKETS)
- *Acheta pennsylvanicus* (Burmeister)
- *Acheta domesticus* (Linnaeus)

NEMOBIINAE (GROUND CRICKETS)
- *Nemobius allardi* Alexander and Thomas
- *Nemobius maculatus* Blatchley

OECANTHINAE (WHITE TREE CRICKETS)
- *Neoxabea bipunctata* (DeGeer)
- *Oecanthus angustipennis* Fitch
- *Oecanthus latipennis* Riley
- *Oecanthus n. nigricornis* F. Walker
- *Oecanthus n. quadripunctatus* Beutenmüller
- *Oecanthus niveus* (DeGeer)

TRIGONIDIINAE (WINGED BUSH CRICKETS)
- *Anaxipha exigua* (Say)

GRYLLOTALPIDAE (MOLE CRICKETS)
- *Gryllotalpa hexadactyla* Perty

APPENDIX B
HABITATS STUDIED

Ann Arbor, a city approximately 45 miles west of Detroit, Michigan, is located in Washtenaw County on the banks of the Huron River in southeastern Michigan. The city is situated in a region of smooth to moderately hilly glacial terrain, except where it is cut by the rather broad, deep valley of the Huron River. The uplands immediately south of the Huron River are ground moraine and glacial outwash; those to the north predominately kames; and the river borders are alluvium and river terraces (U. S. D. A. *Yearbook,* 1938). The soils of Ann Arbor and the outlying districts are loams of the Miami-Crosby-Brookston soil association (U. S. D. A. Soil Survey Washtenaw County, Mich.). Marshes occur near the river margins at elevations of approximately 740 to 780 feet above sea level. The elevation of the uplands generally ranges from 800 to 900 feet. All uplands are cleared and used for housing or industry, except for scattered fields near the outskirts of the city.

Observations were carried out at many different points in the outskirts of the city and beyond, but much time was spent at the conveniently located Nichols Arboretum, which contains the only remaining wooded areas of fair size. The Arboretum is located on the eastern border of Ann Arbor, adjacent to the Huron River. While its wooded areas are not virgin, they are comparatively untouched.

The Edwin S. George Reserve is located about 25 miles northwest of Ann Arbor in the southwestern corner of Livingston County, which is situated in the Miami-Kewaunee soil area (U. S. D. A. *Yearbook,* 1938). The soils of the Reserve are loams, mucks, and peats (U. S. D. A. Soil Survey Livingston County, Mich.). Most of the land below 900 feet of elevation is swampy, generally being covered by shrub-sedge, grass-sedge-fern, or tamarack marshes, but sometimes by hardwood swamps or sphagnum-leatherleaf bogs. The uplands above 915 feet consist of scattered dry fields and hardwood forests not unlike the original oak-hickory forest cleared by the settlers.

Cantrall (1943) discussed the soils, weather, and other environmental factors of the Reserve in his superb ecologic study of the Orthoptera of the area, and Evans and Dahl (1955) recently summarized its weather conditions. Numerous papers describing various aspects of the Reserve's fauna and its ecology have been published. Anyone desiring additional information may turn to these works.

This appendix contains descriptions of many of the stations studied during the course of this investigation, each of which consists of a complex of habitats. It was necessary to make a compromise between economy and complete description. Therefore, only eleven of the most-visited stations are described in some detail; less-frequently visited ones which are the sites of feeding records are briefly described; and all others are omitted.

Each of the eleven detailed discussions includes: (1) comments on location, habitat type, surrounding areas, dominant plants, topography, soil, elevation, and other relevant material; (2) a list of plants subjectively grouped according to abundance; (3) a list of Orthoptera. These lists are not complete but merely include the more prominent and characteristic species seen during successive visits to the stations. They are valuable because they help to characterize the habitat of each station and because they serve as a basis by which feeding records may be evaluated in terms of relative abundance of food-plants.

In view of the great differences in behavior and in habitat selection among the Orthoptera of a given community, a ranking of plant species according to abundance, hence, availability for feeding, is necessarily true for a majority of the Orthoptera, but not for all. The following example will illustrate this point.

Scudderia septentrionalis, a Michigan katydid, is a tree-dweller, whereas a related species, *S. c. curvicauda*, is an inhabitant of the shrub-forb stratum of the same woods. *S. septentrionalis* will accept certain forbs, but these plants are not available in the arboreal stratum in which it normally lives. *S. c. curvicauda*, in contrast, eats flowers and leaves of forbs but seldom eats tree leaves and does not show much liking for them when they are available. Obviously, the significance of the abundance of woody plants of a station differs for *S. septentrionalis* and *S. c. curvicauda*. The same is true for the abundance of forbs or of any of the other kind of food-plant.

Several rather arbitrary criteria were used in the evaluation of plant abundance. So-called *abundant* species are those which occur throughout the community and are sufficiently available for a species to feed exclusively on them; also classed as abundant are those plants which are localized in an almost pure stand composing a fairly large portion of a community, though they are not available throughout the community. *Common* plants are those observed at frequent to infrequent intervals whenever one walks slowly through a community. If a species were restricted to such a food-plant, its individuals might occasionally experience difficulty in finding food, but would not starve. *Uncommon* plants, species so scarce that they might not be seen when one walks through the community, would be unable to support a large population monophagous on them. For this reason, uncommon plants have been omitted from the following lists of abundance of plant species.

The Orthoptera listed as occurring in the stations are not necessarily characteristic of the habitats there represented. Some of them, the "erratics" of Cantrall (1943), are individuals which have wandered from their characteristic habitat and are unable to reproduce in the new situation. An example is the anomalous occurrence of the walking-stick *Diapheromera femorata,* a woodland form, in a marsh (Station 28D). The several walking-sticks found in the marsh must have fallen from the overhanging trees into the marsh border, a situation totally foreign to them.

A detailed description of certain frequently visited stations and a very general one of less-visited stations follows.

Station 4A.—Field between the Huron River and Geddes Road, closely adjacent to Geddes Bridge, Ann Arbor area. This is a former pasture now choked with dense growths of *Rhus.* The habitat is similar to that of Station 17A.

Station 5.—Marsh near the northeastern border of the junction of Michigan Highway 17, United States Highway 23, and Hog Back Road, Ann Arbor area. This is a forb-sedge-grass marsh with large amounts of *Leersia* and *Typha.* The habitat is similar to that of Station 25.

Station 6.—Field directly southeast of the junction of Stadium Boulevard (Highway 17) and Washtenaw Avenue, Ann Arbor.

The edges of this meadow are contiguous with a small stand of hardwoods. The field is dominated by *Phleum*, but its field-wood ecotone is rather mesic, supporting a good growth of *Fragaria, Podophyllum*, and *Viola*. The habitat is rather similar to that of Station 13.

Station 8.—Woods to the east of Service Road, Arboretum, Ann Arbor.[34] This rather mesic oak-hickory woods is traversed by foot paths and bounded by roads and open fields. At its margins, where the woods is lower and somewhat open, there grows a profusion of shrubs, forbs, and scattered trees. At the more heavily wooded summit there is a patch of *Pinus*. Most of the woods is dominated by oak trees, which form a distinct canopy. In the more shaded places the floor is covered by *Carex pensylvanica* and various forbs. *Aster* spp., *Poa Compressa, Solidago* spp., and small shrubs grow along the path margins. This luxurious growth of forbs is in distinct contrast to that seen in the

Abundant [35]

Carex pensylvanica
Cornus stolonifera
Hamamelis virginiana
Lonicera canadensis
Pinus sp.
Poa compressa
Quercus rubra
Quercus velutina
Solidago caesia

Common [35]

Anemone virginiana
Aster laevis
Aster lateriflorus
Aster sagittifolius
Carpinus caroliniana
Carya glabra

Common (Cont.)

Carya ovata
Corylus americanus
Crataegus spp.
Helianthus divaricatus
Juglans nigra
Lonicera tatarica
Monarda fistulosa
Panicum sp.
Prunus serotina
Prunus virginiana
Quercus alba
Rhamnus alnifolia
Rhus typhina
Rubus occidentalis
Solidago canadensis
Vitis riparia

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34 Those parts of the Arboretum and the George Reserve having well-established names will be cited accordingly.

35 See pp. 210 and 163–164 for a discussion of abundant and common species.

more xeric woods of the Reserve. Leaf litter is several inches in thickness. The elevation extends from about 800 to 840 feet. The soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 8 is given above (p. 211).

The following is a list of the Orthoptera observed at Station 8:

Amblycorypha oblongifolia
Amblycorypha rotundifolia
Ceuthophilus brevipennis
Ceuthophilus divergens
Ceuthophilus meridionalis
Ceuthophilus pallidipes
Ceuthophilus thomasi
Diapheromera femorata
Melanoplus s. scudderi
Nemobius maculatus
Nemobius tinnulus
Neoconocephalus ensiger
Neoxabea bipunctata
Oecanthus angustipennis
Oecanthus niveus
Parcoblatta uhleriana
Scudderia c. curvicauda
Scudderia f. furcata
Scudderia septentrionalis

Station 10.—Field to the west of the junction between United States Highway 23 and Dhu Varren Road, Ann Arbor area. A new housing development is encroaching on this small shrubby field, which is choked by a thick growth of many forbs, especially *Solidago* spp., and shrubs, especially *Rhus*. The habitat is similar to that of Station 17A.

Station 11.—Woods to the northwest of Glen Drive, immediately north of Heathdale, Arboretum, Ann Arbor. This is an oak-hickory woods with a well-developed shrub and forb stratum. *Aster macrophyllus, Collinsonia, Desmodium glutinosum,* and *Podophyllum* are some of the common forbs. The habitat is rather similar to that of Station 8.

Station 12.—Field between the intersection of Glen Drive and Locust Knob, Arboretum, Ann Arbor. This field is bounded by low, wooded hills. Approximately one-half of it is low and level, supporting a rather luxurious growth of forbs and grasses, mostly *Dactylis, Plantago,* and *Poa.* The other half is high and rather dry, supporting a more arid type of vegetation, the dominant plants of which are *Achillea, Eragrostis, Panicum,* and *Setaria.* The habitat is similar to that of Station 13.

Station 13.—Field bisected by the Service Road, Arboretum, Ann Arbor. This open field is surrounded by higher, wooded areas. Two-thirds of the field is low, supporting vegetation of the wet-field type; the remaining one-third is hilly, somewhat higher and drier, and its vegetation tends toward the dry-field type. *Achillea, Plantago, Poa,* and *Setaria* dominate the hilly area, in contrast to the rather rich growth of *Danthonia, Fragaria, Plantago, Poa,* and *Trifolium* in the lower, flat area. The field is disturbed by regular mowing. Its elevation is approximately 820 to 880 feet, and its soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 13 is as follows:

Abundant

Achillea millefolium
Dactylis glomerata
Danthonia spicata
Fragaria virginiana
Panicum sp.
Plantago major
Plantago rugelii
Poa pratensis
Setaria glauca
Trifolium repens

Common

Ambrosia artemisiifolia
Aster laevis
Aster sagittifolius
Bromus inermis

Common (Cont.)

Eragrostis spectabilis
Erigeron strigosus
Juncus tenuis
Linaria vulgaris
Medicago lupulina
Oxalis stricta
Phleum pratense
Poa compressa
Potentilla recta
Prunella vulgaris
Rudbeckia serotina
Solidago nemoralis
Taraxacum officinale
Trifolium pratense
Viola papilionacea

The following is a list of the Orthoptera observed at Station 13:

Acheta pennsylvanicus
Amblycorypha rotundifolia
Arphia sulphurea
Chloealtis conspersa
Chorthippus longicornis
Chortophaga viridifasciata
Conocephalus brevipennis
Conocephalus f. fasciatus
Conocephalus strictus
Dissosteira carolina
Encoptolophus s. sordidus
Melanoplus bivittatus
Melanoplus confusus
Melanoplus f.-r. femur-rubrum

Orthoptera at Station 13 (Cont'd.):

Melanoplus keeleri luridus
Melanoplus s. scudderi
Nemobius allardi
Neoconocephalus ensiger
Oecanthus angustipennis
Orphulella speciosa
Scudderia c. curvicauda
Scudderia f. furcata
Spharagemon b. bolli
Syrbula admirabilis
Tetrix subulata
Tettigidea l. lateralis

Station 14.—Marsh adjacent to the western margin of Southwest Woods, George Reserve. The marsh is dominated by associations of sedges (especially *Carex lacustris* and *C. stricta* var. *strictior*), ferns (*Onoclea sensibilis*), and forbs (*Solidago canadensis* and *Verbena hastata*).

Station 15.—Field to the southwest of Miller Avenue, midway between Maple Road and North Seventh Street, Ann Arbor. This shrubby field with a considerable growth of *Melilotus* is now the site of a housing development.

Station 16.—Wooded bank of Liberty Creek, near Park Bridge, Liberty Park, Girard, Trumbull County, Ohio. Tangled forbs, shrubs, and grasses grow in comparative shade under the hardwoods which overlook Liberty Creek.

Station 17A.—Field to the south of the junction of Geddes Avenue and the East Huron River Drive, Ann Arbor area. This shrubby field is bordered by roads and by patches of woodland. When the present study was begun, the field was newly cleared and the vegetation not tangled, but after several years the vegetation became choked, and a primitive road leading to a housing development was built, bisecting the field. The vegetation consists largely of *Aster* spp., *Melilotus alba, Solidago canadensis,* and grasses, with many shrubs, particularly *Rhus glabra,* scattered throughout. The elevation of the station is 780 feet, and its soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 17A is as follows:

Abundant

Achillea millefolium
Aster laevis
Aster sagittifolius
Dactylis glomerata
Daucus carota
Melilotus alba
Monarda fistulosa
Poa pratensis
Rhus glabra
Solidago canadensis

Common

Agropyron repens
Ambrosia artemisiifolia

Common (Cont.)

Aster novae-angliae
Aster pilosus
Erigeron strigosus
Fragaria virginiana
Juncus tenuis
Phleum pratense
Plantago lanceolata
Poa compressa
Potentilla recta
Quercus velutina
Rhus radicans
Rubus flagellaris
Rubus occidentalis

The following is a list of the Orthoptera observed at Station 17A:

Chortophaga viridifasciata
Dissosteira carolina
Encoptolophus s. sordidus
Melanoplus confusus
Melanoplus f.-r. femur-rubrum
Melanoplus s. scudderi
Oecanthus n. nigricornis
Scudderia f. furcata

Station 17B.—Grassy margin of the Michigan Central Railroad tracks at junction with Geddes Avenue, Ann Arbor area. This gravel bank is covered by an almost pure stand of *Andropogon* but also supports some *Bromus inermis* and *Elymus*.

Station 18.—Marsh directly north of the junction of the Huron River and Tubbs Road, Ann Arbor area. This habitat is a typical Huron River marsh, supporting many shrubs, sedges, and forbs, particularly *Eupatorium* spp.

Station 21A.—Field directly northeast of Fuller Road, 0.4 miles northwest of Geddes Bridge, Ann Arbor area. This dry field is bordered by marshes, roads, and scattered patches of woodland. It is rather flat but abruptly slopes downward at the Fuller Road and marsh margins. The vegetation is mostly *Agropyron, Chrysanthemum, Equisetum* spp., *Poa* spp., and *Solidago* spp., together with scattered shrubs, particularly *Cornus*, *Ptelea,* and *Prunus.* The elevation is 800 feet and the soil Bellefontaine sandy loam. In many respects this station is similar to Cantrall's mixed grass-herbaceous ones of the George Reserve.

The relative abundance of the more prominent plants of Station 21A is as follows:

Abundant	Common
Achillea millefolium	*Cornus stolonifera*
Agropyron repens	*Gnaphalium obtusifolium*
Antennaria sp.	*Lespedeza capitata*
Aster pilosus	*Linaria vulgaris*
Chrysanthemum leucanthemum	*Melilotus alba*
Equisetum arvense	*Monarda fistulosa*
Equisetum hyemale	*Ptelea trifoliata*
Erigeron strigosus	*Rudbeckia serotina*
Poa compressa	*Rumex acetosella*
Poa pratensis	*Solidago canadensis*
Potentilla recta	
Solidago juncea	
Solidago nemoralis	

The following is a list of the Orthoptera observed at Station 21A:

Acheta pennsylvanicus
Arphia p. pseudonietana
Chorthippus longicornis
Dissosteira carolina
Encoptolophus s. sordidus
Melanoplus b. bilituratus
Melanoplus confusus
Melanoplus dawsoni
Melanoplus f.-r. femur-rubrum
Melanoplus keeleri luridus
Melanoplus s. scudderi
Oecanthus exclamationis
Oecanthus n. nigricornis
Oecanthus n. quadripunctatus
Orphulella speciosa
Pseudopomala brachyptera
Spharagemon b. bolli
Syrbula admirabilis

Station 22B.—High, grassy banks of the creek, midway between the dam and the stone bridge, Loch Alpine, Ann Arbor area. This area was a pasture when the present study was begun, but it is now the site of a housing development. Grasses and forbs, particularly *Cirsium, Dactylis, Poa,* and *Taraxacum,* were abundant along these banks.

Station 25.—Marsh to the northwest of Cedar Bend Drive, Island Park, Ann Arbor. This seldom-inundated marsh, which is now the site of a housing development, is bordered by a well-traveled road and by higher, cleared ground. The station was formerly encircled by a narrow tree-shrub zone peripheral to a zone of sedges and grasses and a central zone of *Solidago* spp., and other forbs. The elevation is 760 feet and the soil Griffin loam.

The relative abundance of the more prominent plants of Station 25 is as follows:

Abundant

Agrostis alba
Aster lateriflorus
Eleocharis calva
Equisetum arvense
Juncus tenuis
Juncus torreyi
Leersia oryzoides
Solidago canadensis
Solidago graminifolia

Common

Acer negundo
Asclepias incarnata
Aster novae-angliae

Common (Cont.)

Carex retrorsa
Carex stricta var. *strictior*
Carex vulpinoidea
Daucus carota
Eupatorium perfoliatum
Eupatorium purpurem
Fraxinus americana
Lycopus americanus
Lysimachia ciliata
Mimulus ringens
Scirpus atrovirens
Scirpus validus
Tovara virginiana
Typha latifolia

The following is a list of the Orthoptera observed at Station 25:

Amblycorypha oblongifolia
Chorthippus longicornis
Conocephalus brevipennis
Conocephalus f. fasciatus
Melanoplus f.-r. femur-rubrum
Nemobius fasciatus
Neoconocephalus ensiger
Oecanthus n. nigricornis
Orchelimum gladiator
Orchelimum nigripes
Scudderia c. curvicauda
Scudderia texensis

Station 27.—Southwest Field, George Reserve. This dry field is an example of the mixed grass-herbaceous habitat of Cantrall (1943). It is surrounded by open woods and scattered trees. Its most elevated portion is a flat, westwardly directed ridge bordering on Southwest Woods. The crown of the ridge is dominated by *Aristida* and *Rubus,* while the shoulders are dominated by *Monarda* and *Poa compressa.* To the south it slopes down into a swale covered by considerable *Poa pratensis.* Its elevation ranges from 950 to 975 feet.

The relative abundance of the more prominent plants of Station 27 is as follows:

Abundant

Achillea millefolium
Aristida purpurascens
Monarda fistulosa
Oxalis stricta
Poa compressa
Rumex acetosella

Common

Antennaria plantaginifolia
Asclepias syriaca
Daucus carota

Common (Cont.)

Liatris aspera
Panicum oligosanthes
Poa pratensis
Potentilla recta
Rhus glabra
Rhus toxicodendron
Rubus flagellaris
Solidago juncea
Tragopogon pratensis
Hieracium longipilum

The following is a list of the Orthoptera observed at Station 27:

Acheta pennsylvanicus
Amblycorypha oblongifolia
Amblycorypha rotundifolia
Arphia p. pseudonietana
Arphia sulphurea
Atlanticus testaceus
Chloealtis conspersa
Chorthippus longicornis
Conocephalus strictus
Diapheromera femorata
Dissosteira carolina
Melanoplus b. bilituratus
Melanoplus bivittatus
Melanoplus confusus
Melanoplus f.-r. femur-rubrum
Melanoplus keeleri luridus
Nemobius allardi
Neoconocephalus ensiger
Neoconocephalus robustus crepitans
Oecanthus niveus
Oecanthus nigricornis quadripunctatus
Orchelimum sp.
Parcoblatta uhleriana
Parcoblatta virginica
Parcoblatta pensylvanica
Pardalophora apiculata

Orthoptera at Station 27 (cont'd.):

Pseudopomala brachyptera
Schistocerca lineata
Scudderia c. curvicauda
Spharagemon b. bolli
Spharagemon collare
Stethophyma gracile
Syrbula admirabilis

Station 28.—Colonel's Field, George Reserve. This field is another example of Cantrall's mixed grass-herbaceous habitat. Its rather flat surface is bounded by woods, scattered trees, and an unimproved main road. Its vegetation is largely *Aristida, Poa compressa, Solidago* spp., and various other herbs. Swales are not well-developed. The field-wood ecotone contains a few trees, scattered oak and other seedlings, tangled growths of *Rubus,* and various forbs and grasses, while its floor bears considerable leaf litter. This station is similar to Station 26.

Station 28B.—Blow-Out, George Reserve. The Blow-Out, an example of Cantrall's sparsely vegetated sand habitat, is a sandy dry field supporting a xeric association of plants. The northwestern part of the habitat is an area of shifting sands and little vegetation except mosses, lichens, and patches of *Cyperus* and *Panicum.* The remainder, however, is somewhat more generously covered with clumped *Aristida, Lespedeza, Panicum,* mosses, and lichens. The density of plant covering has notably increased since the habitat's description by Cantrall in 1943. The elevation of the Blow-Out ranges from 905 to 920 feet, and its soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 28B is as follows:

Abundant

Aristida purpurascens
Lespedeza capitata
Panicum spp.

Common

Asclepias syriaca

Common (Cont.)

Cyperus filiculmis
Erigeron strigosus
Poa compressa
Poa pratensis
Quercus velutina
Rumex acetosella

The following is a list of the Orthoptera observed at Station 28B:

Arphia p. pseudonietana
Dissosteira carolina
Encoptolophus s. sordidus
Melanoplus b. bilituratus
Melanoplus confusus
Melanoplus f.-r. femur-rubrum
Melanoplus s. scudderi
Schistocerca lineata
Spharagemon b. bolli
Spharagemon collare

Station 28C.—Field margin directly adjacent to the eastern end of Crane Pond, George Reserve. This bank is covered by *Asclepias, Cirsium,* grasses, and other herbs.

Station 28D.—Big Swamp, George Reserve. This marsh, an example of Cantrall's semipermanent marsh habitat, is choked by a dense growth of grasses, sedges, and forbs. The particular section visited in this study is a narrow band somewhat midway between the margin of Big Woods and Big Island. *Calamagrostis, Carex stricta* var. *strictior, Impatiens, Polygonum, Typha,* and ferns dominate the area. *Larix* is restricted to the center of the marsh, while *Rhus* is dispersed throughout it. The elevation is 895 feet and the soil Rifle peat.

The relative abundance of the more prominent plants of Station 28D is as follows:

Abundant

Calamagrostis canadensis
Carex lacustris
Carex stricta var. *strictior*
Carex spp.
Impatiens capensis
Onoclea sensibilis
Phalaris arundinacea
Polygonum sagittatum

Common

Betula pumila
Boehmeria cylindrica
Bromus sp.
Cicuta bulbifera

Common (Cont.)

Cornus stolonifera
Dryopteris thelypteris var. *pubescens*
Equisetum arvense
Eupatorium purpureum
Larix laricina
Populus tremuloides
Potentilla fruticosa
Rhus vernix
Scirpus spp.
Solanum dulcamara
Spiraea alba
Typha latifolia

The following is a list of the Orthoptera observed at Station 28D:

Amblycorypha oblongifolia
Chloealtis conspersa
Chorthippus longicornis
Conocephalus brevipennis
Conocephalus nigropleurum
Diapheromera femorata
Melanoplus bivittatus
Melanoplus f.-r. femur-rubrum
Neoconocephalus ensiger
Orchelimum gladiator
Orchelimum nigripes
Paroxya hoosieri
Pseudopomala brachyptera
Scudderia c. curvicauda
Scudderia f. furcata
Tetrix subulata
Tettigidea l. lateralis

Station 29.—Marsh immediately southeast of Geddes Bridge, Ann Arbor area. This habitat is the permanently marshy border of the Huron River. Its width varies from 10 to 50 feet from the river margin to the railroad embankment which overlooks it. It has three narrow zones: a shrub zone dominated by *Cornus* and contiguous with the railroad embankment; a central zone or marsh proper dominated by *Carex*, *Eupatorium* spp., and *Juncus*; an aquatic zone bordering the river and dominated by *Carex comosa* and *Peltandra*. The elevation is 740 feet and the soil Carlisle muck.

The relative abundance of the more prominent plants of Station 29 is as follows:

Abundant	Common
Agrostis alba	*Cornus stolonifera*
Bidens cernua	*Eupatorium perfoliatum*
Carex comosa	*Lycopus virginicus*
Eupatorium purpureum	*Sagittaria latifolia*
Impatiens capensis	*Scirpus validus*
Juncus effusus	*Verbena hastata*
Leersia oryzoides	
Peltandra virginica	

The following is a list of the Orthoptera observed at Station 29:

Acheta pennsylvanicus
Conocephalus attenuatus
Conocephalus f. fasciatus
Melanoplus bivittatus
Melanoplus f.-r. femur-rubrum
Orchelimum nigripes
Orchelimum volantum

Station 31.—Big Woods, George Reserve. This oak-hickory woods, the shady oak-hickory habitat of Cantrall, occurs on the crown and sides of a rather steep, extensive, esker-like ridge between Big Swamp and a series of depressions to its northwest. The top of the ridge is traversed by a well-traveled, unimproved road. The tall-tree stratum is of oaks and hickories, while the shrub stratum is largely of *Prunus,* though *Gaylussacia* is also very common. The ground stratum is mostly *Carex pensylvanica* and *Pteridium.* The forest floor is covered by an abundant leaf litter and considerable broken branches and twigs. The elevation of the habitat ranges from 900 to 975 feet, and its soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 31 is as follows:

Abundant

Carex pensylvanica
Prunus serotina
Pteridium aquilinum var. *latiusculum*
Quercus alba
Quercus velutina

Common

Carya glabra
Carya ovata
Gaylussacia baccata
Hamamelis virginiana
Hepatica americana
Poa compressa
Quercus rubra
Rubus flagellaris
Sassafras albidum

The following is a list of the Orthoptera observed at Station 31:

Acheta pennsylvanicus
Atlanticus testaceus
Ceuthophilus brevipes
Ceuthophilus meridionalis
Chloealtis conspersa
Diapheromera femorata
Nemobius tinnulus
Oecanthus angustipennis
Parcoblatta pensylvanica
Parcoblatta uhleriana
Scudderia c. curvicauda
Scudderia f. furcata
Scudderia septentrionalis

Station 31B.—Northeast Field, George Reserve. This dry field, an example of Cantrall's mixed grass-herbaceous habitat, is somewhat concave in profile, the resulting variation in soil moisture accounting for much of the interesting vegetational zonation. To the north there is a low ridge, the vegetation of which is mostly *Poa compressa* and *Rumex,* and to the south a gentle rise to the border of Big Woods, the vegetation of which is dominated by *Aristida, Rhus,* and *Solidago* spp. Nestled in the small concavity between the above ridges is an area of *Phleum* and *Poa pratensis,* together with small, localized patches of *Asclepias, Cirsium, Monarda,* and *Setaria.* The elevation of the habitat ranges from 910 to 925 feet, and its soil is Bellefontaine sandy loam.

The relative abundance of the more prominent plants of Station 31B is as follows:

Abundant

Aristida purpurascens
Asclepias syriaca
Cirsium arvense
Monarda fistulosa
Phleum pratense
Poa compressa
Poa pratensis
Rhus glabra
Rumex acetosella

Common

Achillea millefolium

Common (Cont.)

Antennaria spp.
Danthonia spicata
Daucus carota
Desmodium sessilifolium
Erigeron strigosus
Euphorbia corollata
Hieracium longipilum
Lespedeza capitata
Potentilla recta
Rubus flagellaris
Solidago juncea
Solidago nemoralis

The following is a list of the Orthoptera observed at Station 31B:

Acheta pennsylvanicus
Atlanticus testaceus
Camnula pellucida
Chloealtis conspersa
Conocephalus brevipennis
Conocephalus strictus
Dissosteira carolina
Encoptolophus s. sordidus
Melanoplus b. bilituratus
Melanoplus bivittatus
Melanoplus confusus
Melanoplus f.-r. femur-rubrum
Melanoplus keeleri luridus
Nemobius allardi
Neoconocephalus ensiger
Oecanthus nigricornis quadripunctatus
Schistocerca lineata
Scudderia c. curvicauda
Spharagemon b. bolli
Spharagemon collare
Syrbula admirabilis

Station 35.—John Bryan State Park, Ohio. Woodland trail.

Station 36.—Mohican State Park, Ohio. Woodland trail.

Station 37.—Mount Giliad State Park, Ohio. Woodland trail.

Station 38.—Old Man's Cave State Park, Ohio. Wood opening of half-coniferous, half-deciduous woodland. The conifers are largely *Tsuga.*

Station 39.—Stroud's Run State Park, Ohio. Dense woodland with considerable leaf litter.

Station 40.—Yard of house, 624 Packard Street, Ann Arbor. This is a small, partly shaded, grass-covered lawn fringed with cultivated plants, including forbs and shrubs.

APPENDIX C
PLANTS USED IN STUDY

The common and specific names of plants and the classification of plants adopted for this work are those of Fernald's *Gray's Manual of Botany* (1950). Those plants on which feeding was recorded in nature and those used in laboratory feeding tests are listed below.[36] This list includes 197 species belonging to 54 plant families. Virtually all of the determinations were made by the author by reference to standard works and comparison with identified materials in the Herbarium of the University of Michigan, but Dr. Rogers McVaugh and Mr. Jarl Hiltunen kindly assisted in the determination of a number of difficult specimens. Identifications made on vegetative characters alone, in groups where floral or other special features are required for accurate specific naming, were carried with assurance only to the genus or generic section, as the material would permit; the specific names given such plants are approximations. It will be noted that the species are numbered; for economy these code numbers are substituted for the plant names in the report on the differential feeding tests.

Division PTERIDOPHYTA

Family Equisetaceae (horsetails)

1. *Equisetum arvense* (common horsetail)[37]
2. *Equisetum hyemale* (scouring rush)

Family Polypodiaceae

3. *Onoclea sensibilis* (sensitive fern)
4. *Pteridium aquilinum* var. *latiusculum* (brake)

Division SPERMATOPHYTA

Subdivision GYMNOSPERMAE

Family Pinaceae (pines)

5. *Tsuga canadensis* (hemlock)

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36 Plants simply observed in the habitats are named in the habitat descriptions, Appendix B, but are not listed here.

37 The describer's name is not given but can be obtained by reference to Fernald (1950).

SUBDIVISION ANGIOSPERMAE

CLASS MONOCOTYLEDONEAE

FAMILY TYPHACEAE (CAT-TAILS)
6. *Typha angustifolia*
7. *Typha latifolia* (common cat-tail)

FAMILY ALISMATACEAE (water-plantains)
8. *Alisma triviale* (water-plantain)
9. *Sagittaria latifolia* (wapato)

FAMILY GRAMINIAE (grasses)
10. *Agropyron repens* (witch-grass)
11. *Agrostis alba* (redtop)
12. *Andropogon gerardi* (beard-grass)
13. *Aristida purpurascens* (triple-awned grass)
14. *Bromus inermis*
15. *Calamagrostris canadensis* (blue-joint)
16. *Dactylis glomerata* (orchard-grass)
17. *Danthonia spicata* (poverty-grass)
18. *Digitaria sanguinalis* (crab-grass)
19. *Echinochloa crusgalli* (barnyard-grass)
20. *Elymus virginicus* (terrell grass)
21. *Eragrostis spectabilis* (tumble-grass)
22. *Leersia oryzoides* (rice-cutgrass)
23. *Muhlenbergia schreberi* (drop-seed)
24. *Panicum lanuginosum*
25. *Panicum* spp. (panic-grass)
26. *Phalaris arundinacea* (reed-canary-grass)
27. *Phleum pratense* (common timothy)
28. *Poa compressa* (Canada bluegrass)
29. *Poa pratensis* (Kentucky bluegrass)
30. *Setaria glauca* (foxtail)

FAMILY CYPERACEAE (sedges)
31. *Carex communis*
32. *Carex comosa*
33. *Carex pensylvanica*
34. *Carex retrorsa*
35. *Carex stricta* var. *strictior*
35.′ *Carex tribuloides*
36. *Carex vulpinoidea*
37. *Cyperus filiculmis* (galingale)
38. *Eleocharis calva* (spike-rush)
39. *Scirpus atrovirens*
40. *Scirpus lineatus*
41. *Scirpus validus* (great bulrush)

FAMILY ARACEAE (arums)
42. *Acorus calamus* (sweetflag)
43. *Peltandra virginica* (tuckahoe)

FAMILY JUNCACEAE (rushes)
44. *Juncus effusus*
45. *Juncus tenuis*
46. *Juncus torreyi*

FAMILY LILIACEAE (lilies)
47. *Allium cernuum* (wild onion)
48. *Asparagus officinalis* (garden asparagus)
49. *Convallaria majalis* (lily-of-the-valley)
50. *Smilacina racemosa* (false spikenard)
51. *Smilax herbacea* (carrion-flower)
52. *Smilax rotundifolia* (common greenbrier)

FAMILY IRIDACEAE (irises)
53. *Sisyrinchium angustifolium* (blue-eyed grass)

CLASS DICOTYLEDONEAE

FAMILY SALICACEAE (willows)
54. *Populus deltoides* (cottonwood)
55. *Populus tremuloides* (quaking aspen)
56. *Salix* spp. (willows)

FAMILY JUGLANDACEAE (walnuts)
57. *Carya glabra* (pignut)
58. *Carya ovata* (shagbark-hickory)

FAMILY CORYLACEAE (hazels)
59. *Betula pumila* (swamp-birch)
60. *Carpinus caroliniana* (blue beech)
61. *Corylus americana* (American hazelnut)

FAMILY FAGACEAE (beeches)
62. *Fagus grandifolia* (beech)
63. *Quercus alba* (white oak)
64. *Quercus bicolor* (swamp-white oak)
65. *Quercus macrocarpa* (mossy-cup oak)
66. *Quercus rubra* (red oak)
67. *Quercus velutina* (black oak)

FAMILY ULMACEAE (elms)
68. *Ulmus rubra* (slippery elm)

FAMILY POLYGONACEAE (buckwheats)
69. *Polygonum sagittatum* (arrow-leaved tearthumb)
70. *Rumex acetosella* (sheep-sorrel)
71. *Rumex crispus* (yellow dock)
72. *Tovara virginiana* (jump-seed)

FAMILY CARYOPHYLLACEAE (pinks)
73. *Lychnis alba* (white cockle)

FAMILY RANUNCULACEAE (crowfoots)
74. *Anemone virginiana* (thimbleweed)
75. *Anemonella thalictroides* (rue-anemone)

FAMILY BERBERIDACEAE (barberries)
76. *Podophyllum peltatum* (wild jalap)

FAMILY LAURACEAE (laurels)
77. *Sassafras albidum* (white sassafras)

FAMILY CRUCIFERAE (mustards)
77.' *Berteroa incana*
78. *Brassica nigra* (black mustard)

FAMILY HAMAMELIDACEAE (witch-hazels)
79. *Hamamelis virginiana* (witch-hazel)

FAMILY ROSACEAE (roses)
80. *Crataegus* spp. (hawthorns)
81. *Fragaria virginiana* (strawberry)
82. *Potentilla fruticosa* (shrubby cinquefoil)
82.' *Potentilla intermedia*
83. *Potentilla recta*
84. *Prunus serotina* (black cherry)
85. *Rubus flagellaris*
86. *Rubus occidentalis* (black raspberry)
87. *Spiraea alba* (meadow-sweet)

FAMILY LEGUMINOSAE (pulses)
88. *Coronilla varia* (crown-vetch)
89. *Desmodium canadense* (beggar's-tick)
90. *Desmodium glutinosum*
91. *Desmodium illinoense*
91.' *Desmodium paniculatum*
92. *Desmodium sessilifolium*
93. *Lespedeza capitata* (bush-clover)
94. *Lespedeza hirta*
95. *Medicago lupulina* (black medick)
96. *Melilotus alba* (white melilot)
97. *Melilotus officinalis* (yellow melilot)
98. *Trifolium hybridum* (alsike clover)

99. *Trifolium pratense* (red clover)
100. *Trifolium repens* (white clover)

FAMILY OXALIDACEAE (wood-sorrels)
101. *Oxalis stricta* (wood-sorrel)

FAMILY RUTACEAE (rues)
102. *Ptelea trifoliata* (wafer-ash)

FAMILY EUPHORBIACEAE (spurges)
103. *Euphorbia corollata* (flowering spurge)

FAMILY ANACARDIACEAE (cashews)
104. *Rhus glabra* (smooth sumac)

FAMILY STAPHYLEACEAE (bladdernuts)
105. *Staphylea trifolia* (bladdernut)

FAMILY ACERACEAE (maples)
106. *Acer negundo* (box-elder)
107. *Acer rubrum* (red maple)

FAMILY BALSAMINACEAE (touch-me-nots)
108. *Impatiens capensis* (spotted touch-me-not)

FAMILY RHAMNACEAE (buckthorns)
109. *Rhamnus alnifolia* (buckthorn)

FAMILY VITACEAE (vines)
110. *Parthenocissus quinquefolia* (Virginia creeper)
111. *Vitis riparia* (frost-grape)

FAMILY TILIACEAE (lindens)
112. *Tilia americana* (basswood)

FAMILY GUTTIFERAE (St. John's-worts)
113. *Hypericum perforatum* (common St. John's-wort)

FAMILY VIOLACEAE (violets)
114. *Viola papilionacea* (violet)

FAMILY ONAGRACEAE (evening-primroses)
115. *Oenothera biennis* (evening-primrose)

FAMILY UMBELLIFERAE (parsleys)
116. *Cicuta maculata* (spotted cowbane)
117. *Daucus carota* (Queen Anne's-lace)

FAMILY CORNACEAE (dogwoods)
118. *Cornus florida* (flowering dogwood)
118.' *Cornus racemosa*
119. *Cornus stolonifera* (red osier)

FAMILY ERICACEAE (heaths)
120. *Gaylussacia baccata* (black huckleberry)

FAMILY PRIMULACEAE (primroses)
121. *Lysimachia ciliata* (loosestrife)

FAMILY OLEACEAE (olives)
122. *Fraxinus americana* (white ash)
123. *Syringa vulgaris* (common lilac)

FAMILY APOCYNACEAE
123.' *Apocynum androsaemifolium*

FAMILY ASCLEPIADACEAE (milkweeds)
124. *Asclepias incarnata* (swamp-milkweed)
125. *Asclepias syriaca* (common milkweed)
125.' *Asclepias tuberosa* (butterfly weed)

FAMILY VERBENACEAE (vervains)
126. *Verbena hastata* (blue vervain)
127. *Verbena urticifolia* (white vervain)

FAMILY LABIATAE (mints)
128. *Collinsonia canadensis* (richweed)
129. *Glechoma hederacea* (gill-over-the-ground)
130. *Lycopus americanus* (water-horehound)
131. *Lycopus virginicus*
132. *Mentha arvensis*
133. *Mentha piperita* (peppermint)
134. *Monarda fistulosa* (wild bergamot)
135. *Prunella vulgaris* (heal-all)

FAMILY SOLANACEAE (nightshades)

136. *Solanum dulcamara* (bittersweet)

FAMILY SCROPHULARIACEAE (figworts)

137. *Gerardia pedicularia* (gerardia)
138. *Linaria vulgaris* (butter-and-eggs)
139. *Mimulus ringens* (monkey-flower)
139.′ *Penstemon hirsutus*
140. *Verbascum thapsus* (common mullein)
141. *Veronicastrum virginicum* (Culver's-root)

FAMILY PLANTAGINACEAE (plantains)

142. *Plantago lanceolata* (ribgrass)
143. *Plantago major* (common plantain)
144. *Plantago rugelii*

FAMILY RUBIACEAE (madders)

145. *Galium concinnum* (bedstraw)

FAMILY CAPRIFOLIACEAE (honeysuckles)

146. *Lonicera tatarica* (Tartarian honeysuckle)

FAMILY CAMPANULACEAE (bluebells)

147. *Campanula rotundifolia* (bluebell)

FAMILY COMPOSITAE (composites)

148. *Achillea millefolium* (common yarrow)
149. *Ambrosia artemisiifolia* (common ragweed)
150. *Ambrosia trifida* (great ragweed)
151. *Antennaria fallax* (pussy's-toes)
152. *Aster cordifolius*
153. *Aster laevis*
154. *Aster lateriflorus*
155. *Aster macrophyllus*
156. *Aster novae-angliae* (New England aster)
157. *Aster pilosus*
158. *Aster puniceus*
159. *Aster sagittifolius*
160. *Bidens coronata* var. *trichosperma* (bur-marigold)
161. *Cacalia atriplicifolia* (pale Indian-plantain)
162. *Chrysanthemum leucanthemum* (white daisy)
163. *Cichorium intybus* (common chicory)
164. *Cirsium arvense* (Canada thistle)
164.′ *Cirsium vulgare*
164.″ *Erechtites hieracifolia*
164.‴ *Erigeron canadensis*
165. *Erigeron strigosus* (daisy-fleabane)
166. *Eupatorium perfoliatum* (thoroughwort)
167. *Eupatorium purpureum* (sweet joe-pyeweed)
168. *Gnaphalium obtusifolium* (catfoot)
169. *Helianthus divaricatus* (sunflower)
170. *Hieracium longipilum* (hawkweed)
171. *Lactuca biennis* (lettuce)
171.′ *Lactuca canadensis*
172. *Liatris aspera* (button-snakeroot)
173. *Polymnia canadensis* (leafcup)
174. *Rudbeckia serotina* (coneflower)
175. *Solidago caesia* (blue-stem goldenrod)
176. *Solidago canadensis*
177. *Solidago graminifolia*
178. *Solidago juncea*
179. *Solidago nemoralis*
180. *Solidago rigida*
180.′ *Solidago speciosa*
181. *Sonchus arvensis* (field sow-thistle)

182. *Taraxacum officinale* (common dandelion)
183. *Tragopogon pratensis* (goat's-beard)
184. *Vernonia altissima* (ironweed)