A SUMMARY OF STUDIES ON THE AMBUSH BUG PHYMATA PENNSYLVANICA AMERICANA MELIN (Phymatidae Hemiptera)

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Method of Study.—The data on the life cycle and natural foods were largely obtained in the field, whereas those regarding variations in the instars and the weight patterns were secured from captives. Eggs, laid by females swept from wild flowers in September-October and subsequently kept under natural conditions out-of-doors, yielded nymphs in January after exposure for 10 days to 80° Fahrenheit and about 80 per cent relative humidity. Severe freezing and wetting proved necessary to produce hatching. The resulting nymphs and adults were kept individually in shell vials, each vial containing a strip of white blotting paper for support. The bugs were fed on quantitatively varied rations of adult *Drosophila melanogaster* L. and *Musca domestica* L.

Recognition and Life Cycle.—The adult is about 2/5 inch long and colored yellow, brown, and green, with a black band across the reposing wings. Being phlegmatic in temperament, it is readily weighed on the open pan of the balance. Adults may be found from July to October by searching the fresh flowers of various plants, especially mountain mint and Compositae. During this period the eggs are laid shingle-fashion in masses and covered with a golden flocculent matrix. I have not succeeded in finding the eggs in nature, but the females readily deposit them in the vials. Most adults die before November, leaving the eggs to bring the species through the winter. The nymphs hatch in May-June and complete their five instars by July. A feature of special interest is the delay in hatching. Although the embryo develops within the first 10 days after oviposition, it remains unhatched or dormant for nine months or less. Were this prolonged diapause eliminated, the species might realize two generations, instead of one, in a year.

Food and Feeding.—The adult may readily be seen sitting amid the floral parts with its anterior end elevated and alert to capture other insects that visit flowers to feed on nectar, pollen, petals and reproductive structures. As the flowers age and no longer attract its insect food, the bug flies to fresh flowers and more adequate prey. No proof was found that the predator chooses flowers whose colors tend to conceal it. The food insects present are obviously the factors that induce the bug to remain in the flower.

Both the nymphs and the adults are doubtlessly the most efficient predatory terrestrial Hemiptera in our area. They employ their extraordinary fore legs to seize their victims by the mouthparts, antennae, legs or even the wings. So powerful is *Phymata* that it can hold with one front leg a fluttering moth of superior size, and, in not a few cases, is found holding two captives simultaneously. However, the adult male is decidedly less voracious than the somewhat larger, paler female, not only feeding less frequently but also, on the average, on smaller forms of insects.

Relatively small captives are quickly inactivated and their bodies observably enlarged as *Phymata* pumps a fluid into them through its piercing-sucking mouthparts. This fluid, presumably of a salivary sort, seems both to deaden the victim and to liquefy the non-chitinous viscera. Subsequently this dissolved matter is sucked out, leaving the discarded small prey very light in weight and the abdominal segments telescoped sharply inward.

In three years of field work, I removed 832 individual insects from the grasp of adult *Phymata*. These represented 195 species, 131 genera, 54 families and seven orders. Distributed taxonomically, the number of individuals taken were: Coleoptera, 82; Hymenoptera, 216; Lepidoptera, 134; Diptera, 346; Neuroptera, 1; Hemiptera, 52; and Homoptera, 1. All the victims were adults, excepting one small geometrid looper and three hemipterous nymphs of the families Miridae, Nabidae, and Pentatomidae.

Diet in Relation to Performance. —The relation between vital performance and quantity of food taken was studied by setting up series of 10 or 20 bugs in shell vials and providing varying numbers of *Drosophila* and *Musca*. Even the nymphs of the first instar quite readily capture the larger *Drosophila*. In some series *Musca* was supplied to the nymphs in the fourth and fifth instars and the adults. The biological effects of these differentiated diets proved to be measurable in the following terms: percentage of survival among the nymphs, length of the instars, rate of growth; weight, size, longevity, extent of sexual activity, and egg-production, among the adults. Six series of individuals were maintained on dietaries graduated from the minimum barely adequate to bring a few nymphs to adulthood, to an optimum which yielded biological results comparable with the normal performance of bugs in nature. For example, individuals that sucked out only 66 *Drosophila* required 187 days to complete the five instars, whereas nymphs that utilized the equivalent of 541 *Drosophila* grew to adulthood in an average of 50 days. Only one nymph of the low-fed series became adult,—a female, that lived but 15 days, weighed 0.0089 gram, and produced no trace of eggs. By contrast, 15 individuals of the above best-fed series became adults which lived an average of 68 days each; the pairs coupled and mated freely and the seven females among them produced slightly more than 100 eggs each and averaged 0.0602 gram in weight. The data from the intermediate series showed that a female must ingest about 120 *Drosophila* in the nymphal stage and about 225 during adult life in order to attain that state of vigor necessary to the inception of sexual activity and oogenesis. As the dietary was increased, the nymphal life became proportionately shorter, adulthood longer and the productive functions, weight and size greater.

A separate report was published that pertained to the effect of the varied diets on the duration of the instars. When the nymphs were supplied all the flies they can utilize in each and every instar, i.e. fed at a near-optimum rate, the five instars lasted the following average number of days: 7.40, 5.50, 5.60, 7.00 and 10.90 respectively, or a total of 36.40 days. These values, expressed in terms of the percent of time each instar represents in the entire nymphal life, were: 20.35, 15.11, 15.38, 19.23 and 29.95, respectively. It will be seen that the first and fourth instars are equal in duration, as are also the second and third, while the fifth required as many days as the second and third combined. The data for 13 other series show that any instar may be attenuated to various degrees by reducing the diet. However, not all instars in the life of any one individual may be so prolonged. That is, the capacity to extend any instar decidedly beyond the usual length depends on the amount of food utilized in one or more previous instars. While the extreme of flexibility in duration was probably not demonstrated in this study, the ability to far exceed the usual duration is surprisingly great. For instance, one series of eleven low-fed individuals required an average of 138.19 days for the nymphal stage, and one female completed that stage in 185 days. It scarcely need be added that these starved bugs produced no eggs and had a brief adult life.

Economic Status.—This attempt to evaluate the economic status of *Phymata* was based on the 832 insects I had previously taken from the predator in the field. It lead to the deduction that *Phymata* is about as beneficial as destructive to our welfare. However, the principal merit of the undertaking was disclosure of the fact that determination of economic status is highly speculative and inconclusive. This is so because estimation of the economic importance of a predator, and particularly of one known to include 195 species of insect prey in its dietary, involves numerous variables and also much ignorance of the essential facts in the bionomics of the victimized species. Only a few instances need to be indicated to reveal the nature of these variables: (1) Differentials in the economic contributions made by the adults and the larvae of a prey species; in one stage, the victimized species may be beneficial as by pollination or through destruction of weeds, whereas in another stage it may be injurious; (2) a phytophagous stage may consume a variety of plants, some cultivated, some weeds; (3) the two or more generations which a prey species may have in a year can vary greatly in their importance owing to differences in the plant food, prey or hosts available to be attacked in each season; (4) the amount of harm or good performed by a species varies from year to year and from locality to locality; and finally, (5) one individual of a species may function in a friendly capacity, another in a destructive way, e. g. one bee pollenizes the flower of an apple, another a thistle. Estimates must therefore differ sharply from time to time and place to place, even granting that all the data were at hand for each situation.

Weight Pattern.—The discovery that ambush bugs obtained in the field varied greatly in weight prompted this inquiry into the amount, nature and causes of changes in weight during the lifetime of captive individuals. By weighing each daily throughout its nymphal and adult life, a body of data was secured which made possible the following characterization of the "weight pattern."

It was learned that the weight-growth curve of any one instar is essentially like that of any other when the individual is fed at the same relative rate throughout the nymphal life. This curve has the form of an attenuated capital S. The daily weights show that each instar exhibits two rather distinct phases, (1) a feeding-growing phase and (2) a molting phase. The first begins when the new cuticle has set and the nymph resumes feeding, which activity had ceased with the inception of the second phase. In approximately the first three-fourths of the instar, feeding is intense, the intensity decreasing steadily however from day to day. As a consequence of such feeding, the weight rises sharply in the early days of the instar, some individuals displaying increases of 100 percent over the previous day. As the body seems to become saturated with wastes, feeding falls off and eventually ceases, with the result that the weight curve slopes off in the hours preceding the molt. Upon molting, the weight drops still more and sharply, the loss being approximately 10 percent of the pre-molt weight. Not less than 80 percent of this loss is traceable to the evaporation of fluids from the moist new cuticle, the rest to the exuviae. A state of comparative dessication is created by these losses, and it is apparent that this state stimulates the intensive feeding and sharp upswing of weight characteristic of the feeding-growing aspect of the instar.

The amount of increase in weight in any instar depends on the quantity of food ingested and on the sex of the bug, the females generally being heavier than the males. The average newly-hatched *Phymata* weighs about 0.0003 gram. At the end of the first instar, the average weight of 42 individuals had increased to 0.00094 gram, the extremes of variation being 0.0007 and 0.0014 gram. Corresponding values for the other four instars were: second, average, 0.0022, extremes, 0.0014 and 0.0040; third, 0.0065, 0.0041 and 0.0092; fourth, 0.0158, 0.0095 and 0.0231; fifth, 0.0317, 0.0193 and 0.0477 gram.

Investigators concerned with the phenomena of weight in the growing stages of insects have adopted the "growth quotient" as a convenient device to express the amount of net increase achieved in the several instars and the nymphal stage as a whole. The growth quotient is the value obtained by dividing the final weight by the initial weight irrespective of sex and diet. The quotients for the five successive instars of 28 individuals were thus: first, average 2.75, extremes 1.7 and 5.3; second, 2.62, -1.7 and 3.8; third, 2.46, -1.7 and 3.2; fourth, 2.49, -1.8 and 3.2; fifth, 2.1, -1.5 and 2.6. In the course of the entire nymphal life, the 28 individuals doubled their weights an average of 107.7 times, extremes 64.0 and 157.0. However, this great spread in extremes is reduced much when each sex is considered by itself. The males multiplied their weights an average of only 83.0 times as compared with 132.5 times for the females. The extremes for the males were 64.0 and 102.0, for the females 103.0 and 157.0. In other terms, the male nymphs gained an average of about 8000 percent, the females about 13,000 percent.

From their study of the Egyptian mantis, *Sphodromantis bioculata* Burm., Przibram and Megusar reported that the nymphs doubled their weight in each instar. This pattern of increase has come to be known as Przibram's principle of doubling. Reference to the average quotients cited above will show that *Phymata* did not conform to this principle, varying largely upward from it, the variations in the growth quotients depending on sex and the quantity of food provided. It is of interest also that the quotients secured from weights of the exuviae of well-fed *Phymata* correspond fairly well with those from the weights of the living nymphs already given.

Like the nymphs, the adults display weights that vary greatly with sex and diet. The males of all dietary series varied from a low of 0.0185 gram to a high of 0.0391 gram, and the females from 0.0315 to 0.0628 gram. Almost without exception, the adult weighs least on its first day when it has suffered its extreme reduction due to recent molting and has not yet resumed feeding. The peak weight is attained at various time points in adulthood. If the nymph was under-fed, the adult lives only a few days and experiences its maximum weight on the day of molting or soon thereafter. Such adults are very short-lived. But the better- to optimally-fed adults achieve their maxima generally on or after the 10th day and may approach or reach the peak repeatedly afterwards. If fed at an adequate rate, the female maintains her maximum or near-maximum weight until the day of death. The principal factors causing fluctuations are ingestion and egestion, and, in the female, oögenesis and oviposition.

The weight pattern of well-fed adults embraces three fairly distinct phases, the first characterized by a slump in weight due to the losses peculiar to the final nymphal molt, the second by a sharp climb in weight that results from several days of intense feeding, and the third by its generally long horizontal plane interrupted by secondary ascents and descents arising from feeding, egestion, oögenesis and oviposition. Because the males feed less voraciously and the bulk of their sexual products is relatively minute their weight curve in the third phase is subject to a lesser degree of vertical fluctuation than that of the females.

How Much Food is Required to Grow a Bug?—The first step in the approach to this question was to determine how many *Drosophila* the nymphs sucked out in each of the five instars. Second, since it is impractical to weigh each fly just before and immediately after *Phymata* consumes its contents, I adopted an alternate method of securing the weight of substance the nymphs ingested. This method consisted simply of weighing (a) hundreds of whole living *Drosophila* and (b) hundreds of flies emptied of their contents by *Phymata,* whereupon the average weight of (b) was subtracted from the average of (a), the difference representing the bulk of food substance available in the average *Drosophila*. This value proved to be 0.0007643 gram. It was then multiplied by the number of *Drosophila* utilized, the product representing the approximate amount of food substance utilized by an individual in any instar.

In the following report of results, only the data from the third, fourth, and fifth instars are included, this for the reason that the small nymphs in the first two instars lack the capacity to ingest all the substance from a fly in one feeding. The relatively small amount required to complete these early instars was determined by estimation based on observations.

Several general theories are indicated by the data. First, the amount of food required by an individual to complete any instar or the whole nymphal stage is clearly affected by the rate at which food is supplied. To illustrate, each of eight bugs kept on a low diet ingested an average of 0.01290 gram while completing their fourth instar in 20 days, whereas each of 10 bugs kept on a more liberal diet consumed 0.04761 gram while completing the same instar in only 7.5 days. The data for the third and fifth instars and the whole nymphal life show this same kind of differences between low and more liberal diets.

Second, when the amount of raw food ingested is compared with the net increase in weight achieved in any instar it is found that the major part of the food, or approximately three-fourths to four-fifths, is subsequently eliminated as gas, vapor or feces, probably largely the latter, and the remainder, or one-fourth to one-fifth, is converted into somewhat permanent bodily substance.

Third, the under-fed nymphs seem to utilize their food somewhat more efficiently than do the individuals supplied with an amount of food more nearly adequate to realize the innate vital potentialities of the species. That is, the proportion of wastes to permanent bodily structures is greater in well-fed than in low-fed nymphs. As an illustration, note that eight bugs ingested 0.00727 gram in the course of their 9.0-day third instar: of this amount, an average of 73.15 per cent was expended, 26.85 percent converted into body. By contrast, 10 other bugs ingested 0.02063 gram during their third instar of 6.4 days: of this amount, 78.46 percent was eliminated, 21.54 per cent converted into body.

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