

FLOWER VISITS OF INSECTS II.¹

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HYMENOPTERA (ex. bees).

The lower Hymenoptera, 26 per cent of the visitors observed, make only 16.8 per cent of the visits. Of the 437 insect flowers observed, they occur on only 43 per cent, while the bees occur on 95.4 per cent. The only respect in which they resemble the bees and show more efficiency than the flies and Lepidoptera is in the thick proboscides composed of several appendages, so that on many flowers they are more apt to transfer pollen. The flowers showing the greatest numbers of these insects are *Cicuta maculata* 145, *Sium cicutæfolium* 95, and *Pastinaca sativa* 91, with exposed nectar, and *Pycnanthemum flexuosum* 89, and *Solidago canadensis* 81, with concealed nectar.

Of the visits of the lower Hymenoptera, 95.5 per cent are to social flowers, usually with epigynous nectaries. It is held here that these insects have produced no special flowers. They resort to highly specialized social flowers which have been modified by bees. They may have had some influence in further modifying these, especially in the case of fig flowers.

The ecology of lower Hymenoptera is associated with insects on which they are parasitic or with which they provision their nests. They are therefore most abundant in summer when all except Tenthredinidæ reach their maxima. They have no

¹The first number was published in *Psyche* 30: 158-69, 1923. In the table on page 158 the local flora should be 560, with percentages as follows: Ma 27.5, Mi 28.9, Mas 17.3, Mis 21.4, Pol 4.8, Red 29.4, White 39.8, Yellow 30.7. Of the 493 indigenous flowers the percentages are: Ma 25.9, Mi 29.6, Mas 17.0, Mis 22.7, Pol 4.6, Red 29.0, White 40.3, Yellow 30.6. On page 159, line 4, for "41.6" read "about 48". In line 32 "ruby-throated" came from an abortive attempt to shorten "ruby-throated humming-bird" to "ruby-throat." On page 167, line 24, for "seventy" read "seventy-three." Besides the tables mentioned there, each one of the 1288 visitors has its visits distributed under the classes and colors as shown in 3, 173.

relation to flowers except to visit those which suit them and are in bloom when they fly. They make fewer non-pollinating visits than any other of the general groups.

Bembicidæ.—Of 99 visits of 10 species to 49 flowers, 39.3 per cent are to Mis, 32.3 to Mas, 28.2 to Pol, 52.5 to white, 34.5 to yellow, 37.3 to Compositæ, 20.2 to Labiatæ and 13.1 to Umbelliferæ. All visits are to social flowers.

Sphecidæ.—Of 377 visits of 16 species to 110 flowers, 43.2 per cent are to Mis, 27.8 to Mas, 27.3 to Pol, 53.3 to white, 33.4 to Compositæ, 14.8 to Labiatæ and 13.5 to Umbelliferæ. Pol. shows 15.4 per cent of the flowers visited.

Scoliidæ.—Of 133 visits of 7 species to 69 flowers, 45.8 per cent are to Mis, 29.3 to Pol, 20.3 to Mas, 61.6 to white, 31.5 to Compositæ, 15.7 to Labiatæ and 12.7 to Umbelliferæ. This and the two preceding are the only families of wasps showing more than 18.7 per cent of visits under Mas.

Eumenidæ.—Of 461 visits of 31 species to 109 flowers, 62.9 per cent are to Mis, 21.0 to Pol, 60.0 to white, 32.7 to yellow, 33.1 to Compositæ and 22.3 to Umbelliferæ.

Philanthidæ (including *Cerceridæ*).—Of 182 visits of 16 species to 63 flowers, 54.9 per cent are to Mis, 34.0 to Pol, 67.5 to white, 30.2 to Compositæ, 16.4 to Umbelliferæ and 12.6 to Labiatæ. Pol is 23.8 per cent of flowers visited.

Crabronidæ.—Of 253 visits of 27 species to 69 flowers, 49.4 per cent are to Mis, 44.2 to Pol, 68.3 to white, 39.9 to Umbelliferæ and 26.8 to Compositæ. Pol shows 21.7 per cent of the flowers visited.

Vespidæ.—Of 182 visits of 8 species to 82 flowers, 56 per cent are to Mis, 26.3 to Pol, 59.3 to white, 39.5 to Compositæ and 13.7 to Umbelliferæ.

Chrysididæ.—Of 64 visits of 17 species to 35 flowers, 50 per cent are to Mis, 46.8 to Pol, 81.2 to white, 45.3 to Umbelliferæ and 25.0 to Compositæ. Of flowers visited, Mis shows 65.7 and Pol 31.4 per cent.

Larridæ.—Of 105 visits of 19 species to 42 flowers, 50.4 per cent are to Pol, 45.7 to Mis, 80.9 to white, 33.3 to Umbelliferæ, 20.0 to Compositæ and 16.2 to Labiatæ. Of the flowers visited, 57.1 per cent belong to Mis and 33.3 to Pol.

Tiphiidæ.—Of 19 visits of 4 species to 14 flowers, 52.6 per cent are to Pol, 42.1 to Mis, 64.4 to white, 31.5 to yellow, 78.9 to Umbelliferæ and 15.7 to Compositæ. Of flowers visited, 50 per cent belong to Mis, 42.8 to Pol and 42.8 to yellow.

Pompilidæ.—Of 188 visits of 33 species to 47 flowers, 58.5 per cent are to Pol, 36.7 to Mis, 70.7 to white, 39.3 to Umbelliferæ and 19.1 to Compositæ. Pol shows 36.1 per cent of the flowers and Mis 48.9

Nyssonidæ, *Pemphredonidæ*, *Thynnidæ*, *Trypoxylonidæ*, *Bethylidæ*, *Myrmosidæ*, *Formicidæ male*, *Mutillidæ male*.—Of 48 visits of 22 species to 20 flowers, 75 per cent are to Pol, 79.1 to white, 65.9 to Umbelliferæ and 10.6 to Compositæ. Pol shows 50 per cent of the flowers and Mis 40.0.

Wasps.—Of 2111 visits of 210 species to 182 flowers, 49.5 per cent are to Mis, 34.4 to Pol, 63.5 to white, 30.0 to Compositæ, 24.8 to Umbelliferæ and 10.5 to Labiatæ. Of 825 visits of the Philanthidæ, Eumenidæ and Vespidae, 59.6 per cent are to Mis. Of 677 visits of Crabronidæ and the last five groups, 51.8 per cent are to Pol. Of 574 visits before July, the wasps show 46.6 per cent to Mis, 39.3 to Pol, 54.7 to white and 37.6 to yellow, while of 1570 visits after June they show 50 per cent to Mis, 32.9 to Pol, 65.8 to white and 25.2 to yellow. The maximum shifts from A 35.1 to B' 36.7. Of the visits of Scoliidæ, Sphecidae, Bembicidae, Philanthidæ and Vespidae, 13.9; of Eumenidæ, 22.3; and of Larridæ, Tiphiidæ, Pompilidæ, Crabronidæ, Nyssonidæ and Chrysididæ, 42.2 per cent are to Umbelliferæ. Of the visits of Scoliidæ, Sphecidae, Bembicidae, Philanthidæ and Larridæ, 15.2 per cent are to Labiatæ.

Ichneumonidæ.—Of 79 visits of 45 species to 35 flowers, 53.1 per cent are to Pol, 37.9 to Mis, 50.6 to yellow, 49.3 to white, 51.8 to Umbelliferæ and 30.3 to Compositæ. Of the flowers, 54.2 per cent are Mis, 28.5 Pol, 54.2 white and 45.7 yellow.

Braconidæ.—Of 58 visits of 33 species to 23 flowers, 51.7 per cent are to Pol, 32.7 to Mis, 58.8 to white, 41.3 to yellow, 53.3 to Umbelliferæ and 32.7 to Compositæ.

Chalcidoidea, Figitidæ, Evanidæ.—Of 85 visits of 33 species to 25 flowers, 76.4 per cent are to Pol, 75.2 to white and 78.8 to Umbelliferæ.

Tenthredinidæ.—Of 27 visits of 14 species to 15 flowers, 59.2 per cent are to Mis, 33.3 to Pol, 70.3 to yellow, 40.7 to *Salix* and 11.1 to Umbelliferæ.

Non-aculeata.—Of 249 visits of 125 species to 62 flowers, 58.6 per cent are to Pol, 33.3 to Mis, 61.7 to white, 37.8 to yellow, 57.2 to Umbelliferæ and 20.8 to Compositæ. Before July 59.8 per cent of the visits are to yellow and 40.1 to white; after June 76.1 are to white and 23.0 to yellow. The maxima remain under A and Pol, but shift from yellow to white.

The preference is for flowers with exposed nectar and most of the visits are to them in spite of the dominance of other classes. So that *exposed nectar as a determining condition*, is limited to a few visits of the most insignificant of hymenopterous pollinators. Even then it fails except when the flowers are social. Many visitors should probably be left out, being so minute as to be of doubtful value, even if all other guests were excluded.

Lower Hymenoptera.—Of 2360 visits of 335 species to 188 flowers, 47.8 per cent are to Mis, 37.0 to Pol, 62.9 to white, 95.5 to social flowers, 29.0 to Compositæ and 28.2 to Umbelliferæ. Pol shows 11.1 per cent of the flowers visited. Of 28 non-pollinating visits 19 are to Mas and 22 to red. Visits to red are 7.5 per cent compared with 18.8 for the Alps. Ten prefer Mas, 112 Mis, 206 Pol, 240 white and 89 yellow. After June the maximum changes from A 40.6 to B' 36.7. Yellow changes from 41.5 to 25.0.

DIPTERA.

Midaidæ.—Two species prefer Pol and white.

Nemestrinidæ.—The single species prefers Mas and red.

Bombyliidæ.—Of 370 visits of 28 species to 160 flowers, 45.6 per cent are to Mas, 31.6 to Mis, 38.3 to yellow and 50.8 to Compositæ. Of the flowers visited, 35.0 belong to Mas and 28.1 to yellow. Visits to red are 23.7 compared with 75.0 in the Alps. After June the maxima change from Hb 27.7 to B' 66.0, Mis 31.9 to Mas 58.0, white 52.9 to yellow 43.5.

Conopidæ.—Of 238 visits of 15 species to 115 flowers, 47 per cent are to Mis, 25.6 to Mas, 20.1 to Pol, 56.3 to white, 10.9 to Labiatæ, 14.2 to Umbelliferæ and 32.3 to Compositæ. Red shows 13.8 compared with 44.4 in the Alps. After June the maximum shifts from AB 29.9 to B' 43.6. Mas changes from 14.7 to 35.9, yellow from 35.2 to 25.3 and red from 9.8 to 19.0.

Syrphidæ.—Of 1165 visits of 86 species to 203 flowers, 51.5 per cent are to Mis, 20.0 to Pol, 58.8 to white, 33.9 to yellow, 24.4 to Compositæ and 17.8 to Umbelliferæ. Red shows 7.2, in the Alps 29.3. After June the maximum changes from AB 37.8 to B' 47.5. Mi changes from 22.2 to 7.8, Mas from 2.1 to 22.9, yellow from 39.2 to 29.0.

The importance of these flies as pollinators has been greatly exaggerated. The general habit of pollen-eating is shown from the fact that the proboscis is never modified so as to prevent it. In 104 visits of *Syrphidæ* to diclinous flowers 31.7 per cent were to pistillate, and 68.2 to staminate, flowers. This shows pretty decisively their preference for pollen. They make more non-pollinating visits than are made by all other flies together. Of 145 visits of this kind 50.3 per cent are to Ma and 42.7 to red.

The flowers showing the greatest number of *Syrphidæ* are *Sassafras variifolium* 19, *Salix cordata* 22, *Solidago canadensis* 22, *Pastinaca sativa* 26, *Aster ericoides villosus* 30, *Heracleum lanatum* 32.

Empididæ.—Of 162 visits of 24 species to 87 flowers, 48.1 per cent are to Mis, 25.3 to Pol, 60.4 to white, 31.4 to yellow, 12.3 to Roasceæ, 15.4 to Compositæ and 16.0 to Umbelliferæ. Pol shows 12.6 per cent of the flowers visited. Red shows 8 per cent of the visits, in the Alps 30.1. After June the maximum changes from A 38.5 to B' 57.5. The siphonate proboscis was

evidently developed as a predaceous organ, but is also used for sucking nectar. *Parempis clausa* is evidently exclusively anthophilous. It flies 113 days after all of the other species have disappeared. Being 4 per cent of the species, it makes 27 per cent of the visits.

Stratiomyidæ.—Of 53 visits of 13 species to 36 flowers, 45.2 per cent are to Mis, 43.3 to Pol, 60.3 to white, 35.8 to yellow and 41.5 to Umbelliferæ. Red shows 3.7, in the Alps 40.0.

Tachinidæ.—Of 842 visits of 108 species to 158 flowers, 53.4 per cent are to Mis, 29.8 to Pol, 66.5 to white, 25.2 to Umbelliferæ and 33.9 to Compositæ. After June the maximum shifts from A 37.5 to B' 46.3. White changes from 59.3 to 70.1 and yellow from 37.5 to 26.0.

Other Calyptratae.—Of 692 visits of 50 species to 140 flowers, 48.2 per cent are to Mis, 29.6 to Pol and 64.5 to white.

Of total Calyptratae visits, 23 per cent are to Umbelliferæ and 25.5 to Compositæ.

Acalyptratae.—Of 178 visits of 53 species to 59 flowers, 47.1 per cent are to Pol, 43.8 to Mis, 55.0 to white, 43.8 to yellow, 58.4 to Umbelliferæ and 12.3 to Compositæ.

Muscoidea.—Of 1712 visits of 211 species to 191 flowers, 50.3 per cent are to Mis, 31.6 to Pol, 64.3 to white, 31.7 to yellow, 26.6 to Umbelliferæ and 28.3 to Compositæ. Pol is 12 per cent of flowers visited. Red shows 3.9 per cent of the visits, to 14.1 in the Alps. They are probably more important to flowers than the Syrphidæ, since they are usually after nectar. Of the total fly visits 45.3 per cent are made by Muscoidea and 30.8 by Syrphidæ.

Tabanidæ, Scenopinidæ, Pipunculidæ, Leptidæ, Phoridæ.—Of 18 visits of 9 species to 13 flowers, 77.7 per cent are to Pol. 72.2 to white and 72.2 to Umbelliferæ.

Nematocera.—Of 44 visits of 15 species to 24 flowers, 50 per cent are to Pol, 56.8 to white, 43.1 to yellow and 50.0 to Umbelliferæ. These flies are usually associated with more

efficient pollinators and often are so small that they can get the nectar without much probability of touching the anthers and stigmas.

Diptera.—Of 3775 visits of 403 species to 266 flowers, 48 per cent are to Mis, 25.4 to Pol, 59.3 to white, 32.9 to yellow, 21.8 to Umbelliferæ and 28.2 to Compositæ. Mis shows 31.9 per cent of the flowers, Pol 8.6 and white 46.9. One prefers Ma, six prefer Mi, 21 Mas, 158 Pol, 192 Mis, 9 red, 133 yellow, 253 white. Visits to red are 7.7, Alps 22.2, Low Germany 24.2, Berlin Garden 33.1. After June the maximum changes from A 35.4 to B' 48.1. Yellow changes from 37.7 to 28.3. Of 256 non-pollinating visits, 32.8 are to Ma, 21.0 to Mas, 17.0 to Pol and 38.6 to red.

Next to bees, flies visit more species of flowers and make more visits than any other anthophilous insects. Being 31.2 per cent of the species, they make 27 per cent of the visits, 36.8 per cent of the total visits to Pol. The total number of flowers visited is less than that for Bombidæ or Halictidæ. The flowers visited by 62 or more flies are *Solidago canadensis* 62, *Zizia aurea* 63, *Sium cicutæfolium* 71, *Cicuta maculata* 82, *Pastinaca sativa* 113, *Heracleum lanatum* 121, *Aster ericoides villosus* 121. The flowers showing the greatest number of siphonate flies are *Solidago canadensis* 16, *Boltonia asteroides* 18, *Bidens aristosa* 21, *Pycnanthemum flexuosum* 22, *Eryngium yuccifolium* 23 and *Aster ericoides villosus* 31.

The importance of flies as pollinators is greatly exaggerated. They are apt to show as the exclusive visitors in unfavorable weather, or in localities where the flora and insect fauna have been greatly disturbed. The proboscis is usually rather thick so that the pollen readily touches and adheres to it, but the more highly specialized for probing flowers it becomes, the less likely it is to extract the pollen. In the lists have been admitted flies which should probably be excluded on account of their small size, or ability to extract nectar or eat pollen without effecting pollination.

Some flies have taken possession of some non-social flowers which have become adapted to flesh-flies or minute flies. The flowers which the Diptera prefer, however, are highly specialized social flowers, usually with epigynous nectaries, 86.3 per cent of the visits being to social flowers.

LEPIDOPTERA.

Sphingidæ.—Of 22 visits of 7 species to 15 flowers, 54.5 per cent are to Ma, 40.9 to Mas, 63.6 to red, 45.4 to Polemoniales and 13.6 to Labiata. In the Alps visits to red are 63.2.

Other Heterocera.—Of 106 visits of 21 species to 68 flowers, 47.1 per cent are to Mis, 31.1 to Mas, 10.3 to Pol, 48.1 to white, 34.9 to yellow and 57.5 to Compositæ. Red shows 16.9, in the Alps 58.6.

Rhopalocera.—Of 1065 visits of 67 species to 203 flowers, 43.6 per cent are to Mas, 24.3 to Mis, 38.3 to red, 11.0 to Labiata and 36.3 to Compositæ. In the Alps red shows 55.2.

Lepidoptera.—Of 1193 visits of 95 species to 211 flowers, 42.4 per cent are to Mas, 25.9 to Mis, 39.3 to white, 36.8 to red. In the Alps red shows 56.1, Berlin Garden 64.0, Low Germany 70.2. One prefers Mi, 7 Ma, 12 Pol, 22 Mis, 51 Mas, 46 red, 33 white, 16 yellow. Of 175 non-pollinating visits, 52.5 per cent are to Ma, 34.2 to Mas and 57.1 to red. Before July they prefer Mas and red; after June, Mas, Mis, Pol, white and red. The maximum changes from Hb 32.6 to B' 50.1. Visits to non-social flowers change from 48.2 to 7.2.

The structure of the proboscis seems to indicate that the butterflies not only had little, or nothing, to do with the origin of insect flowers but that they did not come into existence until after the highly specialized bee flowers had been developed. The moths are important visitors of few flowers and have influenced the development of few, except in the case of the *Sphingidæ*. Butterflies are large and correspond little with the variable sizes of flowers. Their proboscides average long, so that they are usually able to reach the nectar of the deepest bee flowers. Their relations to flowers are often that of nectar

thieves. The proboscis is exceedingly slender, smooth and dry so that it often does not touch the pollen, or does not readily hold it. On flowers with exerted anthers and stigmas the butterflies are probably the most useful. But even in such cases they often insert their tongues into flowers whose anthers and stigmas they do not touch with their bodies. It is a regular thing for them to visit personate and papilionaceous flowers without any likelihood of touching the anthers. In slender tubed flowers with included anthers they may touch the anthers, but even here there is doubt about much pollen sticking to their tongues. There are probably no slender-tubed butterfly flowers from which bees are excluded and in which bees are not likely to be more useful. A bee's proboscis has from five to seven appendages wet with nectar or honey, and which get so covered with pollen that in mounting it is often necessary to wash the pollen out.

In the percentage of visits, 8.5, over species, 7.3, the Lepidoptera show a slight gain, but in 41 flowers whose visitors were taken as they came they lost in percentage of individuals.

OTHER VISITORS.

Coleoptera.—Of 438 visits of 137 species to 113 flowers, 42.4 per cent are to Mis, 40.8 to Pol, 64.8 to white, 15.2 to Compositæ and 39.4 to Umbelliferæ. One prefers Mas, 48 Mis, 81 Pol, 46 yellow and 88 white. Visits to red are 5.2, in the Berlin Garden 16.9, Low Germany 18.3, Alps 23.2. Of 123 non-pollinating visits, 34.9 per cent are to Mis, 30.0 to Mas and 40.6 to yellow. After June the maximum changes from A 50.9 to B' 46.2.

The flowers showing the greatest number of beetles are *Pastinaca sativa* 42, *Aruncus sylvestris* 33, *Cryptotania canadensis* 19, *Sium cicutæfolium* 19.

Beetles seem to have developed anthophilous habits as a secondary matter, and were probably few on primitive flowers. Some have structures fitting them for obtaining nectar, as

Chauliognathus pennsylvanicus, which has maxillary lobes extensible by 4 or 5 mm, and makes more visits than any other beetle.

Beetles probably have produced no special flowers. They principally resort to social flowers with epigynous nectaries.

Hemiptera.—Of 113 visits of 21 species to 64 flowers, 47.7 per cent are to Mis, 30.9 to Pol, 52.2 to white, 38.0 to yellow, 34.5 to Compositæ and 30.9 to Umbelliferæ. Ten prefer Mis, eight Pol, 11 white and ten yellow. After June yellow changes from 47.1 to 29.0. The maximum shifts from B 39.6 to B' 50.0. The proboscis, though not developed for flower visits, is sometimes used to extract nectar.

The Hemiptera and Coleoptera form 12.2 per cent of the visitors observed, but make only 3.9 per cent of the visits.

Neuroptera.—*Chrysopa plorabunda*, found on some Umbelliferæ with exposed nectar, is not included in the tables.

Birds.—Of 29 visits made by the rubythroat, 82.7 per cent are to Ma, 55.1 to red, 17.2 to Personales, 13.7 to Labiataæ, 13.7 to Leguminosæ, 10.3 to Polemoniales. It picks out the most highly modified and brightest colored of the long-tongued bee flowers. The bird flowers belong to melittophilous groups and have been appropriated by the humming-birds.

Total Visitors.—Of 13971 visits made by 1288 visitors to 437 flowers, 39.8 per cent are to Mis, 20.4 to Mas, 18.7 to Pol, 51.3 to white, 31.7 to yellow, 28.9 to Compositæ and 15.9 to Umbelliferæ. Thirty-six prefer Mi, 44 Ma, 176 Mas, 471 Pol, 511 Mis, 126 red, 390 yellow and 755 white. After June visits to Mas change from 8.3 to 32.7, to yellow from 34.2 to 29.9, and the maximum changes from AB 26.8 to B' 44.6. Visits to red are 16.8 per cent, in the Alps 41.6.

INSECTS AND THEIR IMPORTANCE TO FLOWERS.

Loew's Groups.—If the flower classes A, AB and Po are designated as allotropic, B and B' as hemitropic, and Hb, F and O as eutropic, and the insects are classed according to the kinds

of flowers which they visit, it will be found that those which before July are eutropic, hemitropic or allotropic, are hemitropic after June. Really the highest specialized and latest developed flowers and insects are hemitropic.

Specialization for obtaining Nectar.—The rubythroat, the Lepidoptera, long-tongued bees and some siphonate flies can visit a great many flowers from which short-tongued bees are excluded. They are at some disadvantage on flowers with shallow nectar.

Müller (3,58) states that *Apis* and *Bombus* play by far the most important part in the fertilization of German indigenous flowers. Knuth (2,154) says: "Just as the pollen-collecting apparatus has reached its highest degree of development in *Apis* and *Bombus*, so also has the mouth of the bees become best adapted for rifling the nectar of flowers. It is therefore intelligible that bees belonging to these two genera play a far more important part than any other insects in the pollination of our indigenous flowers." When these bees are compared with other bees having a similar flight, the importance of the specialization of the proboscis and scopa is not so obvious. When 40 species of Halictidæ make nearly as many visits as 133 species of long-tongued bees, it is not on account of a more highly specialized tongue or scopa. The Halictidæ visit 14 more flowers and make 1123 more visits than the Bombinæ, 927 more than Bombinæ and *Apis* together. When *Apis* and *Bombus* make only 13.3 per cent of the visits recorded in Müller's *Fertilisation of flowers*, it is not easy to understand these statements regarding their importance in pollination.

Dependence on a Floral Diet.—The food of bees is almost exclusively from flowers. The fig chalcids and *Pronuba* are about the only insects which can compare with them. The importance to flowers of the nest-provisioning habit is shown by the fact that the nest-making bees average 23.4 visits, while the inquilines average 10.7. The females of the nest-makers average 20.6 visits, while the males average 10.3. The females of the inquilines average 8.8 and the males 8.0.

Number of Species.—On account of having more species, and in spite of a lower average number of visits, the flies and lower Hymenoptera surpass the Lepidoptera; the Halictidæ and Megachilidæ surpass the Bombidæ; the Andrenidæ surpass the Euceridæ; the Muscoidea surpass the Syrphidæ; the Syrphidæ and Bombyliidæ surpass the Conopidæ; the Eumenidæ surpass the Sphecidæ, Vespidae and Scoliidæ; the Crabronidæ and Pompilidæ surpass the Vespidae, Philanthidæ, Scoliidæ and Bembicidæ.

Average Number of Visits.—In spite of the fewer species, the bees surpass the flies in average number of visits. The Bombinæ surpass the Euceridæ, Megachilini, Nomadidæ, Osmiini or Epeolidæ which have more species. The Halictidæ make 1366 more visits than the Andrenidæ, although they have only five more species.

Length of Flight.—The high average for *Apis mellifera*, Bombinæ, Ceratinidæ, Halictidæ and Vespidae is associated with the long flight, the most important condition determining the visits of bees. Bees flying all season are 23.3 per cent of the species and make 51.2 per cent of the bee visits.

Abundance.—Mere commonness is an important condition in determining the visits to flowers. Insects visiting 11 or more flowers are 27.1 per cent of the species and make 77.6 per cent of the visits. The bees, rubythroat and Lepidoptera are the only visitors which gain in percentage of visits over species. Bees gain in percentage of individuals over visits and all other insects lose.

The following insect groups make more than 139.7 visits, one per cent of the total:

Bees 6063 long-tongued 3061 short-tongued 3002.—Halictidæ 1951, Megachilidæ 786, Bombidæ 764, Andrenidæ 585, Euceridæ 521, Nomadidæ 272, Epeolidæ 198, Ceratinidæ 194, Prosopididæ 166, Panurgidæ 141, Colletidæ 140.

Flies 3775.—Muscoidea 1712, Syrphidæ 1165, Bombyliidæ 370, Conopidæ 238, Empididæ 162.

Lower Hymenoptera 2360, *aculeate* 2111, *non-aculeate* 249.—
Eumenidæ 461, Sphecidæ 377, Crabronidæ 253, Pompilidæ 188,
Vespidæ 182, Philanthidæ 182.

Lepidoptera 1195.—Rhopalocera 1065, Papilionidæ 324,
Nymphalidæ 312, Hesperidæ 305.

Coleoptera 438.

PHENOLOGY OF ANTHOPHILOUS INSECTS.

BEES.

With a few exceptions bees are the only flower-visiting insects which are phenologically associated with flowers. Their presence implies the necessary presence of flowers. The composition of the bee fauna for the season or for particular parts of the season is determined by the presence of certain kinds of flowers.

Dasygastræ.

The bees forming the superfamily Trypetoidea differ decidedly from the long-tongued bees in general in forming an earlier maximum. They fly from March 21 to October 22 and have a maximum of 64.5 per cent July 4, 85.4 per cent flying in June. The Stelididæ, May 9—October 18, have a maximum of 83.3 per cent on June 14. The Megachilidæ, March 21—October 22, have a maximum of 69 per cent July 4, 85.7 per cent flying in June. The Osmiinæ, March 21—October 18, have a maximum of 75 per cent June 16, 90 per cent flying in June. The Megachilinæ, May 11—October 22, have a maximum of 95.4 per cent July 4.

Scopulipedes.

Apygidialia.—The Colletoidea, March 20—October 30, with a maximum of 54.1 per cent May 29-31, show 62.5 per cent flying in June. The Prosopididæ, April 20—October 11,

show a maximum of 88.8 per cent May 15—June 9. The Colletidæ, March 20—October 30, show a maximum of 46.6 per cent June 21, 53.3 per cent flying in July and August.

The Ceratinoidea are represented by two Ceratinidæ, March—November, and one of the Xylocopidæ, May 5—July 5.

The Apoidea, represented by Bombidæ and Apidæ, fly from March to November, with all, except one rare species, flying simultaneously June 22-28. The Bombidæ fly from March 15 to November 4. The females appear in March and April, the workers May—July, and the males in July and August. As far as pollination is concerned the maximum of the group is in August.

Pygidialia.—The *Dasygastræ* and *Apygidialia* form old and fragmentary groups characterized by distinct structural marks and by discontinuous geographical distribution. Together they make only 28.8 per cent of the indigenous bees. On the other hand the *Pygidialia* are 71.1 per cent of the species. They are more recent, more plastic, less distinctly separated into groups and of a more continuous geographical distribution.

The Halictoidæ, March 17 to November, have a maximum of 91.3 per cent June 14-15, 93.1 per cent flying in June. The Halictidæ, March 17 to November, have a maximum of 94.6 per cent on June 14-15. Nineteen species have been observed in March and 21 in November. Some are so rare that their flight has not been made out, but it is likely that all are flying simultaneously from June until October. The Dufouroidæ are represented by *Halictoides marginatus*, August 27—October 3. The Nomiidæ are represented by *Paranomia nortonii*, June 26—September 9.

The Andrenoidea fly from March 17 to October 30, and have a maximum of 45.5 per cent May 11-13, 57.3 per cent flying in May. The percentage declines to 19.1 in July and rises again to 32.3 in August and September. The Andrenidæ, March 17—October 30, have a maximum of 60.7 per cent May 11-13, 70.5 per cent flying in May. Only one species is flying July 30—August 12, while six are flying simultaneously September 8-20.

All of the late ones are oligoleges of Compositæ and 44.4 per cent of the early ones are oligoleges of various flowers. *Andrena* and *Pterandrena*, a genus of Compositæ oligoleges, are both separated into early and late groups. The Panurgidæ have the most definite position of any of the dominant families of bees, May 28—October 29, all of them together August 30—September 3, 87.5 per cent being oligoleges. Of the oligoleges 78.5 per cent affect Compositæ. The Macropididæ are represented by *Macropis steironematis*, June 12—July 18.

The Anthophoroidea fly from April 8 to October 22, with a maximum of 58.9 per cent August 8-26, 66.6 per cent flying in July. The Euceridæ, April 8—October 22, have a maximum of 62.5 per cent August 8-28, 68.7 per cent flying in August. *Tetralonia* has a May maximum. All of the other Euceridæ complete their flight between June 13 and October 22, 76.9 per cent being simultaneous in August. Here the polyleges, oligoleges of Compositæ and other oligoleges have a very definite and similar position. The Anthophoridæ fly from April 8 to September 20. The Emphoridæ fly from June 24 to October 7.

Short-tongued Bees.—These fly from March 17 to November, and have a maximum of 58.6 May 18-31, 72.7 per cent flying in May.

Long-tongued Bees.—These fly from March 15 to November, and have a maximum of 48.6 per cent, July 13, 66.1 per cent flying in August.

Bees, Total.—These fly from March 15 to November and have a maximum of 47.2 per cent July 13.

Oligoleges.—That the oligolectic bees are associated in their time of flight with the blooming seasons of the flowers on which they depend is as evident as that the inquiline bees are phenologically associated with their hosts, or that other insects are associated with the time of the insects on which they are parasitic, or with the presence of the food on which their larvæ feed. This is more evident than the converse proposition that the blooming times are correlated with the flight of the oligoleges, for usually the flowers have other visitors which can effectually

pollinate them. Sometimes the oligolege is of no particular use to the flower, so that the relation is quite one-sided. Usually the blooming season of a plant may be explained by the simple statement that it agrees with its relatives, all of which bloom about the same time.

The same statement, however, is true of the oligoleges. They resemble their relatives in time even more than the plants on which they depend. Evidently the groups to which the oligoleges belong were originally quite definitely located phenologically so that their members were in close competition, to avoid which there arose a diversification of food habits, some of the species becoming oligolectic and the others remaining polylectic. In some groups, however, the phenologically correlated relatives were oligoleges of related plants, like *Melissodes* and *Compositæ*. Here the diversification in food habits resulted in some of the species becoming polylectic. The food habits have evidently tended to restrict the oligoleges to the time of their food plants and to give the polyleges more latitude in the extension of the time. Consequently the flight of the oligoleges averages shorter than that of their related polyleges.

Inquilines.—The inquiline bees are phenologically associated with their hosts and have no direct relation to flowers. They visit the flowers most convenient to them. The *Nomadidæ*, *inquilines* of *Andrenidæ*, show evidences of having shortened their proboscides to suit the kinds of flowers which were most common where they were flying. Although they are long-tongued bees, their flower visits resemble those of their short-tongued hosts almost exactly.

Coelioxys consists of *inquilines* of *Megachilini* and the seasons are similar. *Psithyrus*, an inquiline of *Bombus*, has a similar flight.

The *Sphæcodinæ* are evidently *inquilines* of other *Halictidæ*. With the exception of *Proteraner*, they resemble the other *Halictidæ* in the fact that the females appear first and the males later and that they fly all season. The same applies to *Paralictus* which evidently consists of *inquilines* of *Chloralictus*.

Among the Nomadidæ, some species of *Holonomada* may be inquilines of *Tetralonia* and *Melissodes*. In the Pasitidæ, *Holcopasites* is probably an inquiline of Panurgidæ. Of the Melectidæ *Bombomelecta thoracica* is evidently an inquiline of *Anthophora ursina* and *Melecta interrupta* of *Amegilla walshii*.

In the flight of the inquilines there is a marked correlation which often seems to determine the time. Thus *Alcidamea simplex* flies 85 days while its inquiline, *Microstelis lateralis*, flies 43 days. *Neotrypetes productus* flies 144 days while its inquiline, *Stelidium trypetinum*, flies 135 days.

But the phenological position is usually quite inveterate and hereditary, for the inquilines are usually related to their hosts. Ten species of *Triepeolus* are evidently mainly inquilines of Euceridæ. They fly from June 27 to October 21 while the Euceridæ fly from April 8 to October 22. Consequently *Triepeolus* only infests the late Euceridæ. So phenologically the species resemble their relatives more than they do the Euceridæ. One infests *Melitoma taurea*, one of the Emphoridæ. So it seems the genus is more apt to infest an unrelated host flying at the same time than it is to change time to follow the Euceridæ. Some of the early Euceridæ may be infested by *Holonomada*. *Colletes* flies from March 20 to October 30. Their inquilines, *Epeolus*, fly from May 29 to October 23. So there is at least one *Colletes* not infested by *Epeolus*, *C. inæqualis*, possibly infested by some *Nomada*. So that phenologically the Epeolidæ resemble one another more than they do the groups on which they are inquiline.

As in the case of oligoleges, the conclusion is reached that the phenological position is the oldest, most inveterate, and the inquiline habit later and determined by, rather than determining, the phenological position.

OTHER VISITORS.

Lepidoptera.—The presence and time of flight of the Lepidoptera is determined by the occurrence of their food plants. Usually they fly a long time and have more than one brood.

Naturally they occur throughout the flower-blooming season and are most abundant in summer when the most of plants are in vegetation. The butterflies form a long low curve, March 10—November 7, and have a maximum of 80.5 per cent July 7-22, 87 per cent flying in July. *Pronuba* is perhaps the only lepidopter whose season is correlated with, and indicates the presence of, particular kinds of flowers. Butterflies often have food plants which are not entomophilous. Given their food plants and long-tongued bee flowers, they could get along pretty well.

Diptera.—The Diptera fly from March 9 to November 6 and show a maximum of 59.2 per cent July 22-27, 67 per cent flying in June. The Nematocera, April 6—October 18, have a maximum of 50 per cent May 25—June 2, 90 per cent flying in May. The Stratiomyidæ, April 21—August 26, have a maximum of 70 per cent May 18-22, 80 per cent flying in May. The Empididæ, April 10—October 8, have a maximum of 72.2 per cent April 30—May 4, 88.8 per cent flying in May. The Syrphidæ, March 10—November 6, have a maximum of 67.5 per cent June 10-11, 80 per cent flying in May. The maximum of the lower Syrphidæ is May 12-15, while that of the higher is June 10-11. The Muscoidea, March 9—November 6, show a maximum of 69.2 per cent July 26-27. They are 51.6 per cent of the Diptera observed on flowers. The Bombyliidæ, March 21—October 29, have a maximum of 60.7 per cent August 21, 67.8 per cent flying in August. The Conopidæ, April 10—November 3, have a maximum of 76.9 per cent July 4—August 8, 84.6 per cent flying in August.

The flight of Diptera is evidently associated with that of the insects on which they are parasitic, or the presence of the plants, or other food, on which the larvæ feed. None have a primary relation to flowers. Their adaptations to flowers are only to such flowers as happened to be present during their flight. Not more than 18 per cent have siphonate proboscides.

Hymenoptera (ex. bees).—The lower Aculeata fly from March to November and have a maximum of 86.8 per cent July 25-27, 91.7 per cent flying in July and 90.6 per cent in

August. The total lower Hymenoptera have a maximum of 74.5 per cent July 22-27, 80 per cent flying in July and August. They are phenologically associated with their food plants or with the insects upon which they are parasitic or with which they provision their nests. Only the fig chalcids have an important relation to any flower.

Coleoptera.—The Coleoptera, March 21—November 6 have a maximum of 52.6 per cent June 9, 53.1 per cent flying in June.

Hemiptera.—The Hemiptera, April 7—October 23, have a maximum of 68.4 per cent June 28—July 8, 78.9 per cent flying in June.

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