NATURAL ENEMIES AND INSECTICIDES THAT ARE DETRIMENTAL TO BENEFICIAL SYRPHIDAE

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FACTS ABOUT SYRPHIDAE

Flies in the family Syrphidae, called syrphid flies, flower flies, sweat flies, hover flies, or drone flies, belong to the order Diptera, suborder Brachycera, section Cyclorrhapha. They are small, medium, to large flies, smooth or pilose, dull to brightly colored. Many of the most common species are distinguished while in flight by their darting movements and their suspended flight above flowers, whereby they have acquired the name "hover flies."

Almost all types of bees, bumblebees, social wasps and solitary wasps are mimicked by syrphids, and so often does this occur throughout the family that they form one of the most striking examples of what appears to be protective mimicry. The resemblance is complete in some species even to a humming sound while in flight much like that of a bee. The resemblance of *Xylota chalybea* (Wied.) to some of the black hunting wasps is complete, even to a rapid twitching of the wings when resting or moving about on the ground.

Adult syrphid flies may be found almost anywhere, and some are quite common. Most of them visit flowers in sunny spots, but some occur only in woods, in moist places, in fields, or near ants' nests, depending upon their feeding and oviposition habits. Almost any locality, except arid ones, should yield nearly one hundred species over an extended period of persistent collecting, notably during the spring and early summer months. Several state check lists exceed two hundred species.

In economic importance the Syrphidae comprise one of the foremost families of the Diptera. The adult flies of this family are considered by some authorities to be second only to honeybees in importance as pollinators. It is the author's opinion that their importance in this respect varies with the locality, with the plants to be pollinated, and from year to year, bumblebees and other Hymenoptera often being of greater importance in effecting pollination. Adult syrphids frequent flowers and feed upon nectar and pollen. Various species visit many of the same plants frequented by bees, wasps, skippers, and tachinid flies, transporting pollen from flower to flower as they go. It is difficult to measure the great service thus performed. In addition, the larvae of syrphids of several genera are predaceous on aphids and certain other Homoptera. They are generally rated second to the ladybird beetles among the aphidophagous predators. A few species attack Psylliidae (=Chermidae), Cercopidae, and lepidopterous larvae.

Ewing (1914) included syrphids in a list of 14 natural predators on the common red spider, or spider mite, *Tetranychus telarius* L.

The family is a beneficial one, except for a few species wherein the larval stage is injurious to growing bulbs and a few other plants (Wilcox, 1927). Medical annals record several scattered cases of myiasis caused by syrphids larvae, particularly those in the rat-tail maggot group (James, 1947).

Based on his extensive studies in California of Syrphidae and their parasites, Kamal (1926a) stated, "The aphis-feeding syrphids rank as high, and under certain conditions higher, than our common ladybird beetles in their efficiency as plant lice enemies. On account, therefore, of the usefulness of these flies, a study of their natural enemies is of unusual importance from an economic standpoint."

Fluke (1929) ranked Syrphidae first among the natural enemies of the pea aphid, *Macrosiphum pisi* (Kalt.), followed according to their importance in this respect by Coccinellidae, fungus diseases, *Aphidius* (Braconidae), and Chrysopidae.

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Metcalf (1916) considered the syrphid, *Pipiza pisticoides* Will., to be the most important enemy of the wooly apple aphid, *Eriosoma lanigera* (Haus.), in Maine.

Fluke (1929) encouraged the use of certain cultural practices to foster beneficial syrphids, such as the planting or retaining of shrubs and trees which annually harbor plant lice, in areas adjacent to crops which are subject to attack by aphids. Wild raspberry, dogwood, goldenrod, roses, and elms are among the best plants for this purpose. These plants will become infested with aphids, generally other than those species which attack cultivated plants, which, in turn, will attract aphidophagous syrphids. Fluke (1929) cited an instance in Wisconsin in which a small field of peas near an open woods was practically free from aphids, and on almost every vine was a syrphid egg or larva. Another field just a quarter of a mile away, but surrounded by cultivated, pastured, or bare fields, was heavily attacked by the pea aphid, *Macrosiphum pisi* (Kalt.). The latter field was later abandoned and plowed under, as hardly a single good pod developed. A large syrphid, *Scaeva pyrastri* (L.), which is abundant in the far west, consumes many aphids in its development. It is a strong flier and occurs in large numbers. Fluke (1929) suggested its introduction into new localities for the biological control of aphids.

While many syrphids are of little or no economic importance, many species in the following genera are important as predators in the larval stage on aphids: *Allograpta*, *Baccha*, *Mesograpta*, *Melanostoma*, *Paragus*, *Pipiza*, *Scaeva*, *Syrphus*, *Metasyrphus*, and *Sphaerophoria*. Others in the genera *Baccha*, *Pipiza*, *Scaeva*. *Syrphus*, and *Metasyrphus* are predaceous in their larval development on coccids, *Salpingogaster nigra* Sch. is a common enemy of the sugarcane froghopper, *Tomaspis saccharina* Dist., in the British West Indies, and is highly effective in the biological control of this pest. Guppy (1913, 1914) published a fairly good discussion of the propagation and introduction of this syrphid into Trinidad and Tobago for the control of sugarcane froghopper nymphs. The larvae of *Syrphus ropalus* Wlk., being negatively phototropic, retreat to the inner surface of the outer leaves which enclose the heart spike of the cabbage tree of New Zealand (Miller and Watt, 1915), and there they destroy caterpillars of *Venusa verriculata*. *Xanthandrus comptus* Harr. in Europe, in addition to being aphidophagous, has been observed to be a common predator upon larvae of *Pieris brassicae* L., *Cnethocampa pinivora* Tr., and other lepidopterous larvae, according to Smith (1936). *Sphaerophoria sulphuripes* Thomson is recorded by Davidson (1916) as predaceous on the bean thrips, *Heliothrips fasciatus* Perg., in southern California. It is with these beneficial species that this report is concerned.

The larvae of most of these may be found feeding amid colonies of aphids. In some species of the predaceous larvae, the larvae pupate among the aphid hosts upon the foliage, whereas in others they descend to the ground and form their puparia in rubbish. The pronounced tendency toward migration on the part of many mature larvae seems to be induced by a need for fairly moist surroundings for pupation. In fields of aphid-infested crops a scarcity of mature larvae and puparia often is noted. A search usually will reveal that large numbers of larvae have moved to the field margins and have pupated in damp soil along ditch embankments, or in more shaded areas, some penetrating to a depth of 10–15 cm. Often the puparia are massed in great numbers in particularly favorable spots.

Publications dealing with or referring to the Syrphidae are quite extensive, hundreds of papers having been published specifically on Syrphidae. The prepoderance of these, however, are of a taxonomic nature or deal with beneficial activities of aphidophagous Syrphidae. Information concerning enemies of Syrphidae is scattered and incomplete; even less information has been published concerning the effect of insecticides upon syrphids. The greater part of the data published dealing with natural enemies of syrphids are on various parasites, almost all of which belong to the order Hymenoptera.

INSECTICIDES

The information on the effects of various insecticides upon Syrphidae is extremely limited. Reasons for this probably are several: failure to recognize the important role which Syrphidae play in the control of aphids and other pests of ornamentals and agricultural plants, with a corresponding lack of available funds for research on this question, usual inability to avoid harming the beneficial insects when immediate control of a pest by insecticides is needed, and the unwillingness on the part of companies manufacturing insecticides to conduct experiments on the harmful effects of their products on beneficial Syrphidae when it can be anticipated that the results will not enhance the sale of their products.

Research is needed to determine which of two or more insecticides is least harmful to Syrphidae and other beneficial predators and parasites where there is little or no difference, otherwise, in the effectiveness of the several insecticides. From one such series of tests, Morrill (1921) reported that the larvae and adults of the ladybird beetle, ***Hippodamia convergens*** Guer., were unaffected by the application of nicotine dust upon melon vines infested with aphids. Likewise, the larvae of Syrphidae were not affected visibly, and even the adults of ***Aphidius***, a small hymenopterous parasite, largely survived.

Metcalf (1916) investigated the effect of contact insecticides, such as are used for plant lice, on syrphid larvae, in the hope that an effective spray for the aphids could be found which would not destroy the syrphid larvae. In this way the latter might be left on the plants to seek out and destroy any aphids which escaped the spray, and thus tend to make the control measures perfect—a compatibility of insecticide and natural control. From his investigations Dr. Metcalf found that in laboratory tests a solution of Black Leaf 40, 1 to 1000 of water with soap added, killed every aphid and only a small percentage of the syrphid larvae.

In Germany, Grosswald (1934) came to the conclusion that pyrethrum is much less destructive to tachinid and ichneumonid parasites of the nun moth than are arsenical compounds, and that the parasitization in dusted areas is even higher than in those receiving no treatment. This observation is of value when related to internal parasites, but has little significance for external predators, such as the Syrphidae. The important factors here are the degree of kill upon application of the insecticide and the degree of residual action.

In general, insecticides which rapidly lose their effectiveness, such as rotenone, nicotine, pyrethrum, hydrocyanic acid gas, etc., are not so detrimental to the beneficial forms. They may kill the larval or adult predators and adult parasites which are present upon the foliage during the period immediately following the application, but those parasites emerging thereafter, and those predators which soon invade the controlled area, are not affected. As a result often there is a marked increase of parasites and predators in relation to that of the host. A non-volatile material may bring about almost complete mortality of beneficial insects, and consequently no assistance in control is afforded by the beneficial forms. For example, Jancke (1935) has shown that the winter application of tar distillates to woolly apple aphid infestations kills the parasite ***Aphelinus*** so completely that recolonization is necessary the following spring. Similar difficulties have been encountered in the use of DDT, so that its use has had to be abandoned.

New organic insecticides present a serious problem, since many are much more deadly to beneficial parasites and predators than the older insecticides long in use. Also, no chance to build up a tolerance for these new insecticides has been afforded the beneficial insects in so short time.

NATURAL ENEMIES OF SYRPHIDAE

Parasites

By far the most serious enemies of syrphids, at least of the aphidophagous species, are the parasitic Hymenoptera, primarily of the superfamily Ichneumonoidea. Hymenopterous parasites of Syrphidae are found among the following familes: Braconidae, Ichneumonidae, Encyrtidae, Eupelmidae, Pteromalidae, Chalcididae, Figitidae, Ceraphronidae and Diapriidae. Many of the species which are parasitic on or in Syrphidae are specific to one or a few closely related host species. The ichneumon *Diplazon laetatorius* (Fab.) is a notable exception to this rule, having a wide variety of dipterous hosts; it also attacks some Coleoptera and Lepidoptera. This parasite is by far the most common and most detrimental in Ohio. Its distribution is almost universal, and in some years it has been credited with parasitizing upwards of 75 percent of several species of *Syrphus* and *Metasyrphus*. Kamal (1939) reported that during some summers in California, parasitism by *D. laetatorius* amounted to almost 40 percent.

Curran (1920) stated: "It has been found that syrphid larvae of all species are more or less heavily parasitized some years much more severely than others. During 1919, parasites were over twice as numerous as during 1915."

The literature on parasites of Syrphidae is widely scattered, most often consisting of a brief statement of parasites reared from some syrphid. Several papers, however, are worthy of special mention: three papers by Kamal (1926a, 1926b, 1939), a paper by Spencer (1926) which deals with the biology of parasites and hyperparasites of aphids, including a review of the literature, and bulletins by Metcalf (1913, 1916), Fluke (1925, 1929), and Heiss (1938).

The important parasites of syrphids occur in four hymenopterous families: Ichenumonidae, Figitidae, Encyrtidae, and Pteromalidae. Of the ichneumons, the common, previously mentioned *Diplazon laetatorius* is probably the most important. As a parasite, it lays its eggs in the larva of the host or in the egg on a leaf. The adult female destroys many other eggs of syrphids by feeding on them. Kamal (1926a) described observing a female *D. laetatorius* drilling a hole in an egg with her ovipositor and then sucking the contents dry. This predaceous habit has been observed also by Heiss (1938) amd Metcalf (1913). When the egg of the parasite is laid in the egg of the host, the larva does not hatch until after the host larva has hatched. In either case the adult emerges from the host puparium through a ragged hole bitten from the anterior end. One parasite only emerges from each host. The species of *Syrphoctonus*, according to Kamal, oviposit in the larva only.

The encyrtids are multiple parasites, and from five to 30 individuals emerge from one host through a small round emergence hole, usually at the side and ventrad. The species of the genus *Bothriothorax* emerge from both host larvae and host puparia, in which they cause a characteristic, lumpy, cobblestone-like deformation of the body surface. The numerous oval swellings of the surface are indications of internal cavities occupied by the developing parasites. According to Kamal (1926a), *Pachyneuron allograptae* Ashm. (a synonym of *Pachyneuron syrphi* (Ashm.)) and the species of *Conostigmus* are pupal parasites, laying their eggs on the surface of freshly formed puparia.

The figitids (formerly within the family Cynipidae) emerge from the puparia of the hosts, one from a host. Which stage of the host is actually attacked has not been ascertained. All Figitidae in the subfamily Aspiceratinae are parasites in syrphid puparia.

A parasitized puparium can be detected within a few hours after its formation; the integument becomes unusually dark with a brassy or slightly greasy sheen. The puparium often fails to round up properly and is notably more slender than a normal one. If the investigator is still in doubt, it is only necessary to await the normal emergence of the syrphid, which takes an average of seven days in the summer. If the fly does not emerge on schedule it is usually parasitized, for the parasites always take longer for their development than the syrphid. The ichneumons emerge in from ten days to two weeks, the encyrtids in about the same length of time, and the figitids take from 24 to 39 days for their emergence after the pupation of the host.

In the summer, *Diplazon laetatorius* and the encyrtid parasites rank first in importance. During the spring and fall, Ichneumonidae of the genus *Syrphoctonus* are most devastating. Work on the biology of hymenopterous parasites of aphidophagous syrphids is being carried on in the Laboratories for the Study of Beneficial Insects, at the Citrus Experiment Station, Riverside, California. Other investigations of hymenopterous parasites are being conducted at the Laboratory for the Investigation of Insect Parasites, Belleville, Ontario, Canada.

The following table lists hymenopterous parasites of Syrphidae in North America, the species attacked by each parasite, where specific hosts are known, and the distribution of each parasite, according to Meusebeck *et al.* (1951).

TABLE 1

*Hymenopterous parasites of Syrphidae in North America.**

*For references to publications treating parasites in this list, see *Hymenoptera of North America, Synoptic Catalogue*, by Muesebeck *et al.*, 1951.

Parasite	Host	Distribution
Braconidae		
Alysiinae		
Asobara barthii Brues	*Temnostoma balyras* (Walker)	Wis. (Milwaukee).
Ichneumonidae		
Celinae (=Cryptinae)		
Ethelurgus syrphicola (Ashmead)	*Allograpta obliqua* (Say) *Syrphus rectus* O. S.	Atlantic west to Ill. in Transit.and U.Austr.Zones.
Rhembobius abdominalis pacificus (Harrington)	*Eumerus strigatus* (Fall.) *Merodon equestris* (Fab.)	Sask., Colo., Wash., Calif.; Hawaii.
Diplazoninae—Members of this subfamily are parasitic on Syrphidae. They oviposit into the egg or young larva of the host and emerge from the puparium. The species are mostly of northern distribution.		
Diplazon annulatus (Gravenhorst)		Greenland;Europe.
Diplazon laetatorius (Fab.)	*Allograpta exotica* (Wied.) *A. obliqua* (Say) *Baccha clavata* (Fab.) *B. lemur* O. S. *Eupeodes volucris* O. S. *Mesograpta polita* (Say) *Metasyrphus perplexus* (Osburn) *M. vinelandi* (Curr.) *M. wiedemanni* (John.) *Paragus bicolor* (Fab.) *P. tibialis* (Fall.) *Platycheirus erraticus* Curr. *Scaeva pyrastri* (L.) *Sphaerophoria cylindrica* (Say) *S. robusta* Curr. *Syrphus rectus* O. S. *S. ribesii* (L.) *S. vittafrons* Shan. *S. torvus* O. S.	Transcont. in Canad.
Diplazon pectoratorius (Thunberg)		Transcont. and Canad. and Huds. Zones; Eurasia.
D. scutellaris (Cresson)	*Allograpta obliqua* (Say) *Baccha clavata* (Fab.) *Metasyrphus vinelandi* (Curr.) *Sphaerophoria cylindrica* (Say)	Atlantic to 100° W. in Transit., U. Austr., and L. Austr. Zones; Mexico.
D. tetragonus (Thunberg)		Transcont. in Transit. and Canad. Zones; Europe.
D. tibiatorius (Thunberg)	*Eupeodes volucris* O. S. *Sphaerophoria cylindrica* (Say) *Syrphus opinator* O. S.	West of 100° W. from Alaska to Mexico in the Huds., Canad., and Transit. Zones; east of 100° W. in Canad. Zone; Europe.

TABLE 1—(Continued)

Parasite	Host	Distribution
Enizemum ornatum (Gravenhorst)		Alaska, Alta., N. Mex., Greenland; Eurasia.
E. petiolatum (Say)	*Metasyrphus wiedemanni* (John.)	Atlantic to Cont. Divide. Transit.and U.Austr.Zones.
Phthorima bidens (Davis)		N.H., N.Y., W.Va., Mich.,
P. extensor Cushman		Mass., N.Y., N.J., Pa., Md., Va.
Promethes cultriformis (Ashmead)		Atlantic to Sask. in Canad. and Transit. Zones.
Promethes elongatus (Provancher)	*Platycheirus erraticus* Curr. *Sphaerophoria robusta* Curr.	Transcont. in Huds., Canad. and Transit Zones.
P. sulcator (Gravenhorst)	*Sphaerophoria robusta* Curr.	Transcont. in Transit. Zone; Europe.
Syrphoctonus agilis (Cresson)	*Allograpta obliqua* (Say) *Metasyrphus wiedemanni* (John.) *Sphaerophoria cylindrica* (Say) *S. robusta* Curr.	Transcont. in U. Austr. to Huds. Zones.
S. alaskensis (Ashmead)		Alaska (Popof Isl.)
S. albopictus (Davis)		Colo., Alta., Wash., Ore., Calif. Transit. Zone.
S. belangerii (Provancher)		Que. to S. C. and La.
S. compressiventris (Cresson)	*Platycheirus erraticus* Curr.	Transcont. in Transit. Zone.
S. cressonii Davis		Nev.
S. cultriformis (Davis)		Colo.
S. decoratus (Cresson)	*Eupeodes volucris* O. S. *Metasyrphus* sp. *Sphaerophoria cylindrica* (Say)	Pacific to Cont. Divide. Transit Zone.
S. elegans var. *nigritarsus* (Gravenhorst)		Greenland; Europe.
Syrphoctonus foutsi Cushman		Maine, Mass., N. Y., Md., D. C., Ohio, Ill.
S. gillettii Davis		Colo.
S. groenlandicus (Holmgren)		Greenland.
S. humeralis (Provancher)	*Allograpta obliqua* (Say) *Eupeodes volucris* O. S. *Scaeva pyrastri* (L.)	West of 100° from Alaska to Mexico; also in the Transit. Zone east to the Atlantic.
S. laevis Brues		Atlantic to Cont. Divide. Transit. Zone.
S. maculifrons (Cresson)	*Cheilosia alaskensis* Hunter *C. hoodiana* (Bigot) *Eupeodes volucris* O. S. *Metasyrphus* sp. *Paragus tibialis* (Fall.) *Scaeva pyrastri* (L.) *Syrphus* sp.	Minn., Iowa, S. Dak., and Rocky Mts. to Pacific. U. Austr. Zone.
S. melanogaster (Holmgren)		Greenland.
S. minimus (Cresson)		Atlantic to 100° W., L. Austr., U. Austr., and Transit. Zones.
Syrphoctonus pacificus (Cresson)	*Allograpta obliquea* (Say) *Eupeodes volucris* O. S. *Metasyrphus* sp. *Scaeva pyrastri* (L.) *Syrphus* sp.	Rocky Mts. to Pacific, and S. Dak. and Alaska. Transit. Zone.
S. pallipennis (Provancher)		Que.
S. pectoralis (Provancher)		Transcont. in Transit., Canad., and Huds. Zones.
S. pleuralis (Cresson)	*Syrphus torvus* O. S.	Transcont. in Transit. Zone. Atlantic to Cont. Divide. Transit.and U.Austr.Zones.
S. robustus Davis		Alta., Wash.
S. vertebratus Cushman		N. H. (top of Mt. Washington).

TABLE 1—(Continued)

Parasite	Host	Distribution
Zootrephus bizonarius (Gravenhorst)		Transcont. in Canad. and Transit Zones; Europe.
Z. ichneumonoides (Provancher)		Transcont. in Canad., Transit., and U. Austr. Zones; Alaska.
Z. rufiventris (Gravenhorst)	*Platycheirus erraticus* Curr.	Transcont. in Canad. and Transit. Zones; Europe.
Encyrtidae		
Encyrtinae		
Bothriothorax californicus Howard	*Scaeva pyrastri* (L.) *Metasyrphus nitens* (Zett.) *S. opinator* O. S.	Calif.
B. faridi Kamal	*Syrphus opinator* O. S.	Calif.
B. flaviscapus Girault		U. S.
B. nigripes Howard	*Eupeodes volucris* O. S.	N. Mex., Calif.
B. peculiaris Howard	*Metasyrphus wiedemanni* (John.) *Syrphus rectus* O. S. *S. ribesii* (L.)	N.H., N.J., Va., Ill., Wis.
Syrphophagus quadrimaculatae (Ashmead)	*Pipiza quadrimaculata* (Panzer)	S. C., Fla., Miss.
S. smithi Kamal	*Syrphus nitens* (Zett.) *S. opinator* O. S.	Calif.
Eupelmidae		
Arachnophaga aureicorpus (Girault)	? syrphid	S. C., Tex.
Pteromalidae		
Sphegigasterinae		
Pachyneuron siphonophorae (Ashmead)	*Baccha clavata* (Fab.)	N.Y. to N.C., Tenn., and Ill.; Minn., Fla., La., Utah, Calif., Wash.
P. syrphi (Ashmead)	*Allograpta exotica* (Wied.) *A. obliqua* (Say) *Baccha clavata* (Fab.) *Eupeodes volucris* O. S. *Mesograpta polita* (Say) *Paragus tibialis* (Fall.) *Scaeva pyrastri* (L.) *Sphaerophoria cylindrica* (Say) *Metasyrphus nitens* (Zett.) *S. opinator* O. S. *S. rectus* O. S. *S. ribesii* (L.)	Ill., N.C., S.C., Fla., La., Idaho, Calif.
Pteromalinae		
Eupteromalus dubius (Ashmead)	*Mesograpta polita* (Say)	D.C., Ohio, Ill., Iowa, Wis.
Chalcididae		
Chalcidinae		
Spilochalcis hirtifemora (Ashmead)	*Mesograpta polita* (Say) *Platycheirus* sp.	D. C., N. C., Ga., Fla., Tenn., Ohio, Ill., Tex.
Figitidae		
Aspiceratinae—parasites in the puparia of Syrphidae. (No data are given by Muesebeck *et al.* on species of Syrphidae pupae from which these parasites have been recovered.)		
Paraspicera bakeri Kieffer		Wis., Ill., Md., D. C.
P. clarimontis (Kieffer)		Calif.
P. utahensis (Ashmead)		Utah.
Prosaspicera albihirta (Ashmead)		Fla.
P. similis (Ashmead)		Maine, N.H., Mass., N.Y., Conn., Pa., Ind., Ill., Mich., Wis., Idaho, Que.
Callaspidia provancheri Ashmead		Maine, N.H., Mass., N.Y., Conn., Pa., Ind., Ill., Mich., Wis., Idaho, Que.

TABLE 1—(Continued)

Parasite	Host	Distribution
Ceraphronidae		
Conostigmus ater Fouts.	syrphid puparium	Calif.
Conostigmus timberlakei Kamal	*Allograpta obliqua* (Say)	Calif. (San Diego).
	Sphaerophoria cylindrica (Say)	
C. zaglouli Kamal	*Scaeva pyrastri* (L.)	Calif.
	Syrphus opinator O. S.	
Diapriidae		
Diapriinae		
Diapria conica (Fab.)	*Eristalis tenax* (L.)	
		and Mich.; Kans.

Fungi

Certain entomogenous fungi are known to attack Syrphidae. Sweetman (1936) recorded that: "Perhaps *Empusa* is the most widely known of these fungi. *Empusa muscae* Cohn has long been known as a parasite of muscid, syrphid, and other flies appearing in the autumn as a halo-like mold enveloping the fly and ramifying throughout its tissues." Occasionally, this fungus kills large numbers of muscoid and calliphorid flies, but it is doubtful that it constitutes a serious threat to the Syrphidae under normal field conditions. *E. muscae* belongs to the class Phycomycetes ("algal fungi"), order Entomophthorales, family Entomophthoraceae (Empusaceae of some authors). Distribution is apparently throughout the temperate-tropical world. Most of the significant observations on the fungus have been made in the United States, Europe and South America.

BIRDS

Folsom (1922) recorded the English sparrow and the chickadee as important natural enemies of the aphid. Dudley (1924) reported on the beneficial work of red-winged blackbirds. Three birds were shot and their digestive systems examined; there were estimated to be 250 undigested pea lice to each bird. Dudley stated that other birds undoubtedly eat the aphids, besides those mentioned, and that it is conceivable that birds might also partake of any predator present at the same time, such as the larvae of Syrphidae, although there are no experimental facts to substantiate this.

Metcalf (1913) stated: "It seems probable that the adults of many species of Syrphidae are a considerable source of food for insectivorous animals of all kinds, especially birds and amphibians. The king-bird, phoebe and flicker are known to feed on *Eristalis tenax* (L.), but I am not able to give much detailed data on this point."

It is reasonable to assume that a wide variety of birds, including various wood peckers, sparrows, and flycatchers, feed upon syrphid imagos, or upon syrphid larvae and pupae, both the exposed, aphidophagous forms and the species which are found beneath bark, in decaying wood, in exuding sap of trees, and in semi-liquid media.

PLANTS

Metcalf (1913) further stated: "The common milkweed, *Asclepias* sp., is a rather formidable enemy of adult Syrphidae. When the latter visit these flowers, their legs are caught by the peculiar and well known pollinia of this plant. In collections one finds a good many specimens with these pollinia clinging to their legs. Large numbers of the weaker-bodied Syrphidae become permanently entrapped by the flowers, thus not only invalidating the remarkable specialization on the part of the flower, but resulting, after long and fruitless struggle, in the death of the fly. So common is this entrapment that I found it well worthwhile, when collecting, to visit these flowers. I have found as high as twenty individuals entrapped on a single head." Numerous observations of the author substantiate these findings.

OTHER CAUSES OF MORTALITY

Undoubtedly, toads, lizards, spiders, and insects such as dragonflies, predaceous Hemiptera, and marauding ants, take a heavy toll on both adults and immature Syrphidae. Many more are killed by automobiles. Still others are trapped in houses and often may be found dead at the bases of windows. During the summer of 1950 the author took several specimens of small *Mesograpta marginata* (Say) trapped behind large picture windows high atop the Empire State Building, in New York City. Sieving devices, aphidozers, harvesters, and other machines used in cultivation and harvesting of crops, destroy large numbers of syrphid larvae. Dudley (1924) reported that in experimenting with an aphidozer to collect pea aphids from pea fields in Wisconsin, he collected with the aphids 1,523 syrphid fly larvae from two and one-half acres. Johnson (1900) recorded that in packing peas in southern Maryland, the separators sieved out in a few days about 25 bushels of larvae of Syrpidae, chiefly one species.

Because of the remarkable resemblance of many syrphids to Hymenoptera, there is a widespread misbelief that adult Syrphidae are stinging insects. Many of the smaller species frequently light on the hands or face of a field worker, apparently attracted by the salt deposits on the skin, and are ruthlessly killed by the worker, who believes them to be "sweat bees." Many times a farmer, seeing the small syrphid larvae on the foliage of his crop and believing them to be responsible for the wilting and spotting of the foliage, has sprayed with an insecticide, only to destroy the agents which have been checking the aphid responsible for the damage, and which in time, might have entirely controlled the aphid infestation.

Climatic factors play a primary part in determining the numbers of syrphids which develop and their longevity, but that subject is not within the scope of this paper.

CONCLUSIONS

Additional investigations are needed to determine the effect of modern insecticides upon Syrphidae. Beneficial activities of syrphids need greater recognition. Possibilities of introducing Syrphidae into new areas, or encouraging an increase of those already present, for the control of aphids and to supplement pollination of crops, needs further investigation, especially in relation to the cost of continued use of insecticides for aphid control.

LITERATURE CITED

Curran, C. H. 1920. Observations on the more common aphidophagous syrphid flies (Dipt.). Can. Ent., 52: 53–55.

Davidson, W. M. 1916. Economic Syrphidae in California. Jour. Econ. Ent., 9: 454–457.

Dudley, J. E. 1924. Control of pea aphis, in 40th Ann. Rept. of Direct. Wis. Agr. Expt. Sta. for 1922–23. Bul. 362: 61–64.

Ewing, H. E. 1914. The common red spider or spider mite. Ore. Agr. College Bul. 131.

Fluke, C. L. 1925. Natural enemies of the pea aphid (*Illinois pisi* Kalt.); their abundance and distribution in Wisconsin. Jour. Econ. Ent., 18: 612–616.

Fluke, C. L. 1929. The known predaceous and parasitic enemies of the pea aphid in N. A. Wis. Agr. Expt. Sta. Res. Bul., 93: 1–47.

Folsom, J. W. 1922. Entomology with special reference to its ecological aspects. 502pp. P. Blakiston's Son & Co., Philadelphia.

Grösswald, K. 1934. Zur Biologie und Oekologie von *Parasetigena segregata* Rond. und *Sarcophaga schützei* Kram. (Dipt.) nebst Bemerkungen über die forstliche Bedeutung der beiden Arten. Zeitschr. Ang. Ent., 21: 1–23.

Guppy, P. L. 1913. Life-history of the syrphid fly predaceous on froghopper nymphs. Trinidad and Tobago Dept. Agr. Bul., 12: 159–161.

Guppy, P. L. 1914. Breeding and colonizing the syrphid. Trinidad and Tobago Dept. Agr. Spec. Circ., 10: 217–226.

Heiss, E. M. 1938. A classification of the larvae and puparia of the Syrphidae of Illinois exclusive of aquatic forms. Ill. Biol. Monograph, 16(4): 1–142.

James, M. T. 1947. The flies that cause myiasis in man. U. S. D. A. Misc. Pub. No. 631: 148–154.

Jancke, O. 1935. Über den Einfluss einiger Blutlaus-Bekämpfungsmittel auf die Entwicklung des Blutlausparasiten *Aphelinus mali*. Arb. Physiol. Ang. Ent. Berlin, 2: 96–98.

Johnson, W. G. 1900. Notes upon the destructive green-pea louse (*Nectarophora destructor* John.) for 1900. U. S. D.A., Div. Ent. Bul. 26: 55–58.

Kamal, M. 1926a. A study of some hymenopterous parasites of aphidophagous Syrphidae. Jour. Econ. Ent., 19: 721–730.

Kamal, M. 1926b. Four new species of parasites from aphidophagous Syrphidae (Hymenoptera). Can. Ent., 58: 283–286.

Kamal, M. 1939. Biological studies on some hymenopterous parasites of aphidophagous Syrphidae. Egypt. Min. Agr. Tech. and Sci. Serv. Bul. 207: 1–110.

Metcalf, C. L. 1913. The Syrphidae of Ohio. Ohio Biol. Survey, Bul. 1: 1–123.

Metcalf, C. L. 1916. Syrphidae of Maine. Maine Agr. Expt. Sta. Bul. 253: 193–264.

Miller, D., and **M. N. Watt.** 1915. Contributions to the study of New Zealand Entomology, from an economical and biological standpoint. New Zealand Inst. Trans. and Proc., 47: 274–284.

Morrill, A. W. 1921. Notes on the use of nicotine dusts. Jour. Econ. Ent., 14: 394–400.

Muesebeck, C. F. W., K. V. Krombein, H. K. Townes. 1951. Hymenoptera of America north of Mexico. U. S. D. A. Monograph No. 2. 1420 pp. U. S. Gov. Print. Office, Washington, D. C.

Smith, H. D. 1936. Le Syrphidae *Xanthandrus comtus* Harris Predateur de la Chenille processionaire du pin (*Cnethocampa pinivora* Tr.). Soc. Ent. de France Bul. 41: 328–329.

Spencer, H. 1926. Biology of the parasites and hyperparasites of aphids. Ann. Ent. Soc. Amer., 19(2): 119–151.

Sweetman, H. L. 1936. The biological control of insects with a chapter on weed control. 461 pp. Comstock Pub. Co., Inc., Ithaca, New York.

Wilcox, J. 1927. Observations on the life history, habits and control of the narcissus bulb fly, *Merodon equestris* Fabr. and the lesser bulb fly, *Eumerus strigatus* Fallén, in Oregon. 19th Bienn. Rept. Ore. St. Bd. Hort., pp. 149–158