Hackman & Meinander 1979

Ann. Zool. Fennici 16:50—83. 1979

Diptera feeding as larvae on macrofungi in Finland

WALTER HACKMAN & MARTIN MEINANDER

Hackman, W. & Meinander, M. 1979: Diptera feeding as larvae on macrof
in Finland. — Ann. Zool. Fennici 16:50—83.

During the summers of 1974—1977 about 3700 sporophores of 184 sp of macrofungi, mainly Agaricales, were examined for infestation with dipte larvae. Diptera were reared from about one-third of the sporophores and pos results were obtained from 148 fungus species.

The principal families of fungivorous Diptera were Mycetophilidae (53 s and Anthomyiidae (16 spp.). About 120 species of Diptera were recor Association with macrofungi has arisen numerous times during evolution in Diptera; certain fungivorous species are generally saprophagous, others may on decomposing matter in the fungus, and among the truly fungivorous sp different degrees of specialization are found, in some cases including tende towards monophagy. The specialized species belong to Mycetophilidae, Phor Platypezidae, Syrphidae, Anthomyiidae, Fannidae and Muscidae.

Developmental and reproductive strategies of fungivorous Diptera as we protecting strategies by the fungi against the Diptera are discussed.

Competition between fungus-feeding dipterous species is probably impo in some cases; for example from a single sporophore of *Leccinum scabrum* 12 diffe species of Diptera were reared.

The economic importance of the Diptera as pests of edible fungi in Fin is discussed.

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1. Introduction

Rautavaara (1974) calculated that about 80 000 tons of edible fungi are produced annually in the Finnish forests, only a small part being utilized as food. Often, however, they are unsuitable as human food because of the heavy insect infestation (Fig. 6). Some fungus species are more frequently infested than others (cf. Rautavaara 1947:225) and in the same fungus species infestation may show annual and seasonal variation. The aim of this study is to describe the relative importance of the different species of Diptera as pests of edible, inedible and poisonous fungi in Finland and to give ecological data on the fungivorous Diptera. Some results on the Anthomyiidae have been published earlier (Hackman 1976).

Large-scale studies on fungivorous Diptera have been carried out in Germany (Eisfelder 1954, 1955, 1956, 1961, 1970), England (Buxton 1960), Switzerland (Burla & Bächli 1968), Hungary (Dely-Draskovits 1972a, 1972b, 19 Dely-Draskovits & Mihályi 1972, Dely-Dra vits & Papp 1973, Dely-Draskovits & 1976a, 1976b, Papp 1972) and Siberia (B kova 1962, only a short summary seen). associated with wood-rotting higher fu Wisconsin, U.S.A., were studied by Ac & Shenefelt (1973). In Germany, Pl (1969, 1971) reared numerous species of tophilidae from higher fungi.

2. Material and methods

The investigation was started in summe favourable year for fungal sporophores in m Finland. In 1975 the summer was dry, and began later than usual, but during Septe October we and several cooperators obtained able amount of material. In 1976 and 1977 was done on a smaller scale. In 1976 mush scarce in SW Finland, and severe night fr end to the season in early October. The ra of 1977 was again favourable for mushroom

Collecting sites

	Commune	10 × 10 km grid	Collectors
[illegible]	Porvoo/Borgå	669:42	O. Biström
[illegible]	Tenala/Tenhola	666:28	K. Pihlström
[illegible]	Kirkkonummi/ Kyrkslätt	667:35	G. Lundqvist
[illegible]	Evo	678:39	G.-B. Lindholm, R. Tuomikoski
[illegible]	Kirkkonummi/ Kyrkslätt	667:35	H. Harmaja
[illegible]	Tenala/Tenhola	665:27	K. O. Donner
…vesi	Haapavesi	711:42	P. Koskela
…ki/ …fors	Helsinki/ Helsingfors	667:38, 667:37	W. Hackman, M. Meinander and others
[illegible]	Ekenas/ Tammisaari	665:31	W. Hackman
…kala	Janakkala	675:36	G.-B. Lindholm
[illegible]	Kuusamo	735:60	
[illegible]	Karis/Karjaa	666:31	M. Meinander
…iainen	Kauniainen/ Grankulla	668:37	A. Pekkarinen
…la,	Kiikala	671:30	A. Albrecht
…perä	Espoo/Esbo and Kirkkonummi/ Kyrkslätt	668:36	W. Hackman
…maa	Kirkkonummi/ Kyrkslätt	668:36	W. Hackman
…mi Biol. …on	Lammi	677:39	W. Hackman, G.-B. Lindholm, M. Meinander & R. Tuomikoski
…jöholm	Askainen	672:21	L.v. Haartman
…senvaara	Kuusamo	735:61	E. Ohenoja
[illegible]	Espoo/Esbo	669:37	W. Hackman & M. Meinander
[illegible]	Lovisa/Loviisa	670:45	M. Meinander
…aby	Kirkkonummi/ Kyrkslätt	666:36	G. Lundqvist
…rby	Espoo/Esbo	668:37	W. Hackman
…pes	Närpes	694:20	M. Meinander
…nsö	Ekenäs/ Tammisaari	665:29	A. Albrecht
…anka …l. Station	Kuusamo	736:59	W. Hackman & E. Ohenoja
…linge	Borgå l.k./ Porvoon mlk.	667:43	Anonymous
…nkasalmi	Punkaharju	685:62	B. Lindeberg
…otsinkylä	Tuusula/Tusby	669:38	M. Korhonen
…nsala	Turku/Åbo	671:23	W. Hackman & M. Meinander
…änäs	Sjundeå/Siuntio	667:30	W. Hackman
…ibbo	Sibbo/Sipoo	668:39	W. Hackman & M. Meinander
…ogby	Tenala/Tenhola	665:29	C. Oker-Blom
…uru	Pohja/Pojo	667:30	W. Hackman
…öderby	Ekenäs/ Tammisaari	665:30	K. Forssblom
Taivalkoski	Taivalkoski	727:55	E. Ohenoja
Tvärminne Zool. Station	Hangö/Hanko	664:28	W. Hackman, M. M. Meinander & C. Oker-Blom
Tuvkulla	Espoo/Esbo	668:37	U. Cedercreutz
Vaala	Vaala	716:49	L. Saaristo

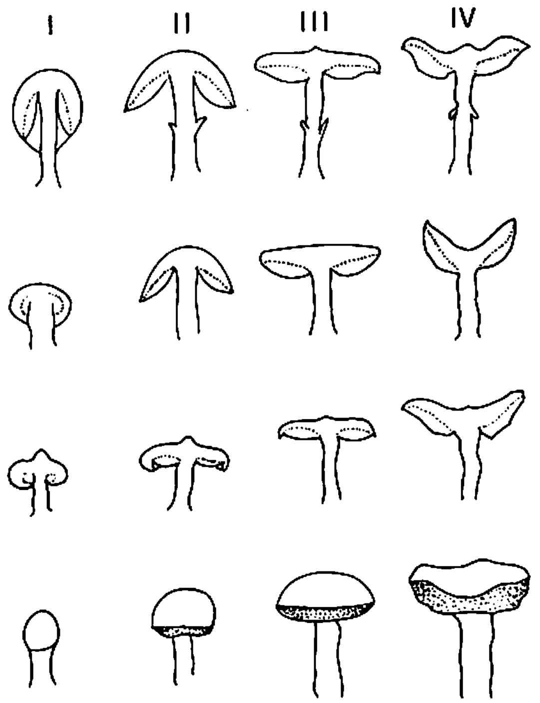

Fig. 1. Sporophores of stages I—IV of *Amanita*, *Russula*, *Lactarius* and *Boletus*.

The sampling localities are listed in Table 1. The bulk of the material was collected at Tvärminne Zoological Station in 1974, in Esbo: Kolmperä in 1974—1977, at Lammi Biological Station in 1975, in Närpes in 1974 and at the Oulanka Biological Station in 1975.

In all, about 3700 sporophores of singly growing fungi or colonies of aggregated fungi were examined. The material comprised 184 species, mainly Agaricales. The sporophores were identified as to species and grouped by age (Fig. 1) into four stages, and the cap diameters measured.

More than 1200 sporophores (or parts of them) representing 179 species were placed in plastic containers on a layer of flower-pot soil. The containers were covered with nylon gauze. Older but not rotting sporophores were chosen if material was plentiful. In some cases the cap and stem were cultured separately. Some 900 cultures of 148 species gave positive results.

For rearing anthomyiid larvae from sporophores of Boletaceae, more special equipment was used to avoid blocking of the maggots' stigmata with the sap of the decaying fungi (Fig. 2). During the summer months the rearing jars were kept outdoors in the shade. The jars were checked frequently. In autumn the cultures were moved to a moist laboratory room with a temperature of +10°C. Towards the end of October the jars were moved to a room at +4°C for a week and then for 2 months at 0°C and finally to room temperature for hatching. In 1974 most of the material was kept in an unheated building until February or March. Before the winter most of the material was searched for puparia, which were placed in soil in small plastic or glass containers.

In some cases (*Pegomya* spp.) many puparia remained unhatched during the next warm season and during the following winter were again kept cold. Many flies emerged after this second hibernation.

In 1976—1977 some puparia kept in a small outdoor cellar throughout the winter were transferred to an unheated building in the spring to show the normal hatching time of the species.

Traps of the type used by Nuorteva (1959) were used to sample dipterans from growing mushrooms in Tvärminne and Kolmperä. Only a minor part of the trapped material is treated in this paper.

3. The dipterous fauna of the different fungi

The fungus species are listed according to the systematics used by Ulvinen (1976). For each species the list gives collecting sites, and numbers of sporophores (sph) of singly growing fungi and colonies for which the rearing results were positive (e.g. 18 sph cultured). Where necessary the stages (= age classes) of the fungi investigated are indicated with Roman numerals. The Diptera reared from the species are listed and the number of specimens reared/number of sporophores or colonies, and month of infestation are given for each species.

For the fungus species investigated by us all dipterous species reared by previous authors but not by us are also listed.

A sporophore is considered infested when larvae or galleries are found. The infestation percentage is calculated from the sporophores of stages II+III only.

Macrofungi other than Agaricales

Because of their importance as edible mushrooms, eight species of fungi belonging to groups other than Agaricales were studied to a small extent.

Helvellaceae: The two *Gyromitra* species investigated are infested with polyphagous species of Diptera, the infestation in *G. esculenta* being very rare and of no practical importance.

Cantharellaceae: The three species investigated are extremely rarely infested with dipterous larvae, and when they are, it is with polyphagous species, mainly Tipulidae, Limoniinae.

Hydnaceae: As in Cantharellaceae, infestation is very rare; some infestation by polyphagous Limoniinae is recorded.

Poriaceae: Only the soft and edible *Albatrellus ovinus* was investigated. The most important pests are the *Megaselia*. Poriaceae with hard perennial sporophores, which were not investigated, are infested with a number of Diptera not found in fungi with soft short-lived sporophores (see Buxton 1960).

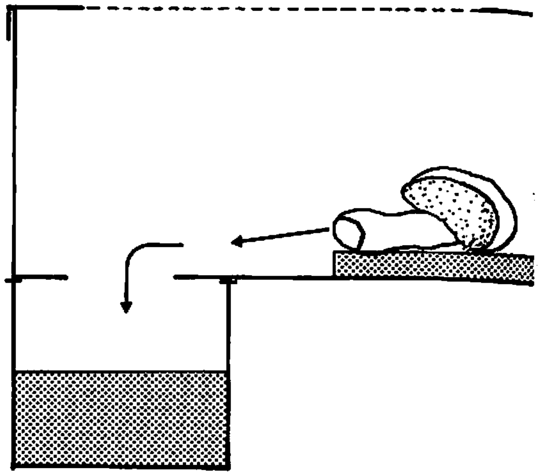

Fig. 2. Rearing box for dipterans infesting large Boletaceae.

1. *Gyromitra infula* (Fr.) Quél. Sibbo 1974, Lammi 1975 (2 sph).

Limonia quadrinotata 16/1 Sept; *L. bifasciata* 2/1 Sept; *Psychoda lobata* 2/1 Sept; *Allodia (Brachycampta)* sp. 1/1 Sept; *Megaselia* sp. (black) 1/1 Sept; *M.* sp. (yellow) 2/1 Sept; *Suillia bicolor* 1/1 Sept; *Suillia atricornis* 1/1 Sept.

2. *G. esculenta* (Pers.) Fr. Haapavesi 1973 (1 sph).

Drosophila transversa 10/1 June, data given by Outi Muona.

3. *Cantharellus cibarius* Fr. Tvärminne 1974, Kolperä 1974—1977 (2 Sph).

Very few of the hundreds of sporophores investigated were infested. Limoniid larvae were found in 3 sph. *Mycetophila fungorum* 1/1 Aug; *Suillia bicolor* 1/1 Aug.

Additional species recorded: (Dely-Draskovits 1972a, 1974, 1977, Dely-Draskovits & Mihályi 1972, Dely-Draskovits & Papp 1973, Plassmann 1969): *Li[illegible] bifasciata*, *Ula sylvatica*, *Sciophila hirta*, *S. lutea*, *[illegible] bimaculata*, *Drosophila testacea*, *D. phalerata*, *D. trans[illegible]*, *Pegomya winthemi*, *Phaonia populi*, *Suillia fuscicornis*, *Tri[illegible] lineella*.

4. *C. tubaeformis* Fr. Kolmperä 1974.

Limoniine larvae were found in a few sporop[illegible] Less than 1 % of the hundreds of sporophores exam[illegible] were infested.

5. *Craterellus cornucopioides* (Fr.) Pers. (Cantharella[illegible] Kolmperä 1977.

A limoniine larva was found in one sporophore[illegible] few sph infested.

6. *Hydnum rufescens* Fr. Kolmperä 1974—1977.

A limoniine larva was found in one sporop[illegible]

7. *Sarcodon imbricatum* (Fr.) Karst. (Hydnaceae)[illegible] 1975 (2 sph).

Trichocera hiemalis 2/1 Sept; *Suillia atricornis* 2/1[illegible] the last (? third) larval instar is obligatorily predacious. We have tried to rear *Mydaea* larvae from eggs on an agar medium with mycelium of *Marasmius scorodonius*, but the larvae died when half grown. In one case fungus gnat larvae were added as prey and then at least one larva pupated (but unfortunately died as a puparium). The *Mydaea* species are polyphagous but at least *M. discimana* shows a preference for Boletaceae. *Mydaea* species lay their eggs on the lamellae (or in the pores of the Boletaceae) or on the cap surface.

Among Phaoninae *Alloeostylus diaphanus* is a polyphagous fungivore. The characteristic yellowish larva hibernates before pupation. *Muscina assimilis* (Muscinae) sometimes occurs in fungi but the larva has saprophagous and predacious habits and is more common in other habitats.

Mydaea tincta (Zetterstedt), 15, 21, 24, 42, 66b, 85, 137, 138, 154, 161, 167, 175.
M. setifemur Ringdahl, 19, 24, 66b, 78, 82, 83, 85, 137, 143, 148, 154, 160, 161, 164, 169, 171.
M. detrita (Zetterstedt), 13, 16, 17, 19, 84, 169:
M. discimana Malloch, 14, 15, 16, 17, 19, 21, 27, 78.
M. electa (Zetterstedt), 21, 87, 164.
Alloeostylus diaphanus (Wiedemann), 17, 83, 169.
Muscina assimilis (Fallén), 114.

Helcomyzidae

The genus *Suillia* is known to be fungivorous and several species have been bred from Agaricales by us. They all seem to be polyphagous without host preference and sometimes they occur in fungi avoided by other Diptera.

Suillia flava (Meigen), 144.
S. flavifrons Zetterstedt, 160.
S. bicolor Zetterstedt, 1, 3, 13, 164, 169.
S. fuscifrons Zetterstedt, 169.
S. atricornis Meigen, 1, 8, 12, 13, 19, 50, 52, 60, 79, 83, 100, 123, 125, 134, 136, 148, 160, 161, 162, 164, 165, 167, 169, 170, 171.

Sphaeroceridae

Among the rather few species bred from comparatively fresh mushrooms only *Limosina parapusio* seems to be a true fungivore; the other species are known to be saprophagous and their larvae probably feed on decomposing fungus tissue. *Limosina parapusio* is thought to be parthenogenetic (Papp 1972) and there are only females in our material.

Copromyza (Copromyza) sp. ,136.
Limosina fungicola Haliday, 15, 64.
L. claviventris Strobl, 64, 138, 164, 166, 169.
L. parapusio Dahl, 15, 28, 55, 78, 94, 120, 139, 169, 175.
L. luteilabris Rondani, 15.
L. heteroneura Haliday, 15.

Carnidae

Two specimens of *Meoneura neottiophila* were reared by us from *Leccinum scabrum*. This fly, known to have a saprophagous larva, has not previously been bred from fungi.

Meoneura neottiophila Collin, 15.

5. The association of Diptera with fungi

A. General aspects

Compared with the interaction between phytophagous insects and vascular plants, the interaction between fungivorous dipterans and macrofungi is basically different. The phytophagous insects may injure their host plants to a degree that has given various protective properties a selective value and led to certain types of co-evolution, and to a trend towards monophagy for the insect. For example, the poisonous plant *Daphne mezerum* is attacked by a monophagous insect, the moth *Anchinia daphnella*, but is immune to polyphagous phytophages. For the soft macrofungi it does not greatly matter whether the soon decomposing sporophore is eaten by larvae in the cap tissues or in the stipe provided spore formation and dispersal are secured; even larval damage to lamellae or to the spores is rarely serious. Egg-laying Diptera visiting ripe sporophores may actually contribute to the spread of spores. Fungi filled with larval galleries do not usually collapse until stage IV. In young sporophores (stage I) of certain groups protective properties against too early dipterous attack can be observed:

1. The sporophore only emerges from the soil at a stage close to stage II. An example is *Lactarius necator*.

2. The unripe basidia (on lamellae or in pores) are protected by a volva or cortina, sometimes mucous and sticky, or by fringes of an inwardly bent cap edge. This prevents oviposition on the basidial layer in stage I. There are numerous examples among our commonest mushrooms.

Cordyla species and *Pegomya incisiva* deposit their eggs in the stipes of sporophores, even young ones, and against these pests a volva,