ORGANISMS, ESPECIALLY INSECTS, ASSOCIATED WITH WOOD ROTTING HIGHER FUNGI (BASIDIOMYCETES) IN WISCONSIN FORESTS

J. K. Ackerman and R. D. Shenefelt
Lakeland College—Sheboygan
University of Wisconsin—Madison

ABSTRACT

A general survey of insects associated with macro-fruiting bodies of forest fungi was made by collecting 511 lots of fungi over a four year period which involved 112 species of fungi in 56 genera. Forty-seven of these were specifically associated with wood and 30 cause damage of importance to the timber industry. The study was undertaken primarily to determine whether or not insects might be useful in control of these injurious forms. A total of 25,379 organisms were obtained from the mushrooms and brackets, with 15,314 belonging to insects in 13 orders. The insects encountered ranged from visitors to those totally dependent on the fungus for development. The majority of organisms, though not necessarily linked to the fungi, were capable of developing in them. Parasites, predators and microorganisms formed a complete ecological community within one macro-fruiting body. Studies of life cycles, population development, host destruction, host ranges and seasonal movement of organisms into and out of fruiting bodies were made.

To determine whether insects may play a role in regulating the abundance of forest fungi in Wisconsin and to assess the possibilities of their being useful as biotic agents for control of wood-rotters, a preliminary survey of the insects associated with the fungi was conducted and their relationships with the hosts examined. Basidiomycetes, especially the Agaricaceae, Hydnaceae, Thelophoraceae (soft-bodied mushrooms) and Polyporaceae (brackets) are the major agents causing heart-rot of trees. It has been known for over 100 years that their sporophores provide microhabitats for a variety of arthropods, and that many of these, especially insects, actually feed upon fungal tissue.

Several authors (Anderson 1936; Austin 1933; Barnes and Buxton 1953; Kessel and Kessel 1939a, 1939b; Pielou 1966; Pielou and Matthewman 1966; Pielou and Verma 1968; Weiss 1920; Weiss and West 1920, 1921) have listed insect genera and species found on or in various fungi. A few have conducted ecological studies on fungus-related fauna (Falcoz 1921, 1927, 1930; Graves 1960, 1965; Graves and Graves 1966a, 1966b, 1968, 1969; Heatwole 1968; Hubbard 1892; Lawrence 1967; Liles 1956; Pace 1967) and a specialized vocabulary relating to the fungus microhabitat was presented by Graves (1960).

MATERIALS AND METHODS

Over a four-year period (1966–69) 511 lots of fungi were collected in 21 counties (32 sites) in Wisconsin (Figure 1). In the field the samples were placed in individual plastic bags and upon return to the laboratory each was transferred to an ice cream carton provided with a water wick [dental roll inserted through the bottom] and a Saran-wrap cover. Paper towels were placed in the cartons to help maintain humidity or to prevent accumulation of moisture in the bottoms. After six months at room temperature the fungi were subjected to cold treatment, one week at 40°F followed by two to four weeks at 0°F, in an attempt to break any resting or dormant state of the insects. Emerging organisms were preserved in 80% ethyl alcohol, pinned or used in rearing.

Methods of rearing varied with the organisms involved. Larvae of fungus gnats (Mycetophilidae) were successfully reared in petri dishes containing Czapek's Agar covered with a piece of filter paper on which a piece of the fungus involved was placed. Petri dishes containing a layer of slightly moist soil, half of which was covered by a piece of filter paper, and containing a piece of fungus were satisfactory for the rearing of *Thalymus fulgidius* Erickson (Ostomidae). Glass vials, provided with strings in contact with water and plugged with cotton, served for the incubation of individual pupae.

THE HOSTS

Consideration was given to insects on both wood attacking and non-wood attacking fungi as knowledge of the alternate hosts for potentially valuable insects was essential. Table 1 gives the fungi studied, those starred being important to the timber industry. All of the fungi except *Sarcoscypha* (#172, 173) belong to the Basidiomycetes. The numbers shown for "Location by County" refer to the numbers given in Fig. 1.

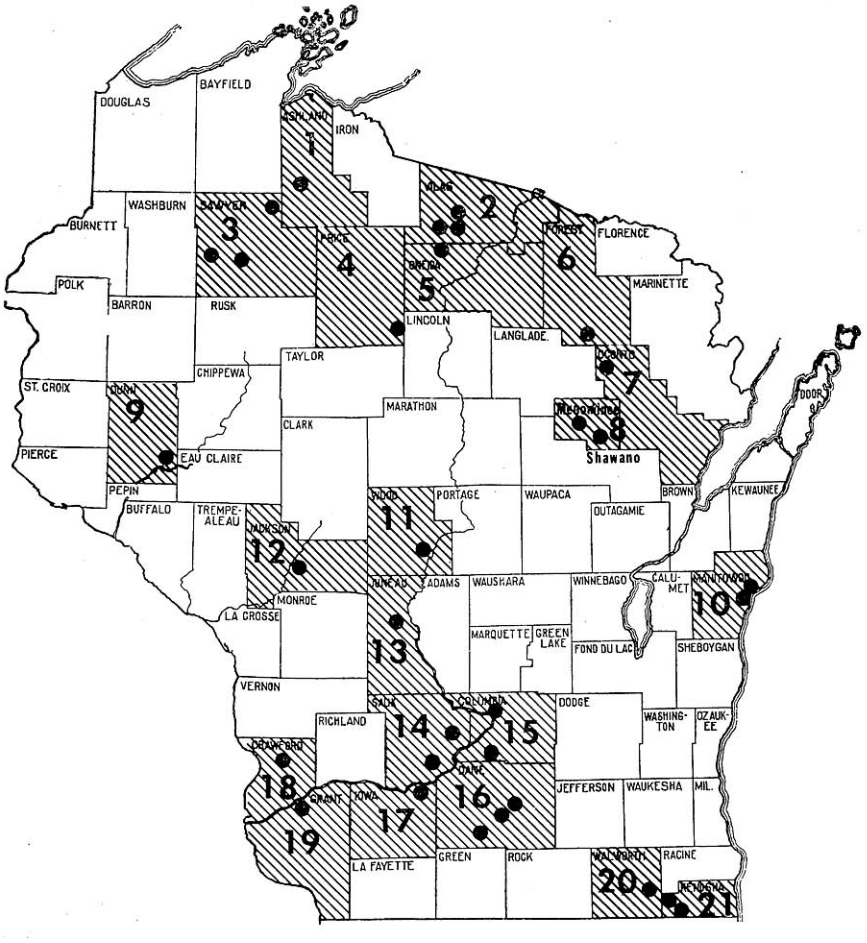

Figure 1. Distribution of collection sites.

ORGANISMS ASSOCIATED WITH THE FUNGI

The animals occupying or visiting the fungi are presented in the faunal check list. A total of 25,379 organisms was obtained from the fruiting bodies. Of this number 10,165 were arthopods other than insects, i.e., centipedes, millipedes, mites, and spiders, or were snails. Insects, representing 13 orders, comprised the remaining 15,214 specimens and were associated with 13 of the 17 families of fungi (Table 2).

TABLE 1. COLLECTION DATA FOR THE FUNGI.

Collection No.	Fungus species	Months collected	Location by county**
1	*Cantharellus* sp.	July–Nov.	7, 8, 10, 12, 20
2	*C. cibarius* Fr.	July, Nov.	17, 20, 21
3	*C. infundibuliformis* Fr.	July	17
4	*C. vinecolor* (Pk.)	Sept., Nov.	5, 10, 20, 21
5	*Clavaria* sp.	July, Sept.	5, 16
6	*C. aurea* Pers.	July, Sept.	2, 5, 7
7	*C. botrytis* Pers.	Nov.	20
8	*C. cinerea* Bull.	Sept.	2
9	*C. stricta* Pers.	July, Sept.	2, 5, 12
10	*Clavariodelphus ligula* Pk.	Sept.	2
11	*Clavulina* sp.	Sept.	2
12	*C. cristata* (Holmsk.) Fr.	Sept.	2
13	*Physalacria inflata* Pk.	June	3
14	*Ramaria* sp.	Sept.	12
15	*R. apiculata* Fr.	Sept.	16
16	**Fistulina hepatica* (Huds.) Fr.	Oct.	10
17	*Porothelium* sp.	May–Nov.	1, 2, 3, 5, 7, 9, 10, 16, 21
18	*Dentinum umbilicum* Fr.	Oct.	10
19	*Hydnum cyathiforme* Schaeff.	Sept.	2
20	*H. imbricatum* L. ex S. F. Gray	Aug, Oct.	8
21	*Lopharia* sp.	Oct.	10
22	*Phlebia* sp.	Oct.	10
23	**Merulius tremellosus* Schrad. (Fr.)	Oct.	10
24	*Trogia crispa* Fr.	June	3
25	*Stereum* sp.	Sept.	16
26	**S. frustulatum* (Pers.) Fr.	June	3
27	*S. ostrea* Blume et Nees	May	16
28	*S. tuberculosum* (Grev.) Fr.	June	3
29	*Thelephora terrestris* (Ehrh.) Fr.	Sept.	11
30	**Cyclomyces* sp.	Oct.	10
31	*Daedalea* sp.	Aug.	2
32	*D. confragosa* (Bolt.) Fr.	Feb.–Nov.	1, 5, 7, 10, 14, 20, 21,
33	**D. unicolor* (Bull.) Fr.	March	14
34	*Favolus* sp.	Nov.	20
35	*F. alveolaris* (DC. ex Fr.) Quél.	Sept.	11
36	*Fomes* sp.	July, Oct., Nov.	1, 2, 6, 10, 20
37	**F. applanatus* (Pers.) Gill.	March, July, Aug., Oct., Nov.	1, 2, 5, 10, 11, 12, 17, 20, 21
38	**F. fomentarius* (Fr.) Kickx	Aug.–Oct.	2, 5, 10, 11, 12
39	**F. everhartii* (Ell. & Gall.) V. Schr.	Aug.	11
40	**F. ignarius* (L.) Gill.	June, Oct.	10, 11
41	**F. officinalis* (Vill.)	Oct.	10
42	**F. pini* (Thore.) Lloyd	Aug., Oct.	8
43	*F. subroseus* (Weir.) Overh.	Sept.	8
44	*F. sulphureus* Fr.	Sept.	2
45	**F. pinicola* (Swartz.) Cke.	Sept.	2
46	**Laetiporus sulphureus* (Bull. ex. Fr.) Murr.	July–Sept.	2, 16
47	*Lenzites* sp.	Oct.	10
48	*L. betulina* (L.) Fr.	June	3
49	**L. sapiara* (Wulf.) Fr.	July	11, 15
50	*Polyporus* sp.	June, July, Sept., Oct.	1, 2, 5, 7, 10, 16
51	*P. abientinus* Dicks. ex Fr.	July	2, 3
52	**P. adustus* (Willd.) Fr.	July, Sept., Nov.	1, 5, 12, 20
53	*P. albellus* Peck.	May–Nov.	5, 7, 16, 20
54	**P. alveolaris* Bosc. ex Fr.	Sept.	11
55	*P. anceps* Pk.	Sept.	5
56	**P. arcularis* Batsch ex Fr.	June	10
57	**P. betulinus* (Bull.) Fr.	July–Oct.	3, 5, 10
58	**P. brumalis* (Pers.) Fr.	July	10
59	*P. cincinnatus* (Bull. ex Fr.) Bondarzew & Singer	Aug.	13
60	*P. cinnamoneus* Jacq. ex Fr.	July	9
61	*P. compactus* Overh.	June	10
62	**P. fibrillosus* Karst.	May, July	2, 16
63	**P. frondosus* Dicks. ex Fr.	July, Sept., Dec.	6, 16, 20
64	**P. gilvus* (Schw.) Fr.	May	16
65	*P. hirsutus* Wulf. ex Fr.	July	3
66	**P. lucidus* Leys. ex Fr.	Sept.	5
67	**P. nidulans* Fr.	July	1
68	**P. obtusa* Berk.	Sept., Oct.	11
69	*P. pargamenus* Fr.	July	1
70	*P. perennis* L. ex Fr.	Oct.	11
71	**P. picipes* Fr.	July	10
72	**P. pubescens* Schum. ex Fr.	Sept.	2

TABLE 1. (CONTINUED)

Collection No.	Fungus species	Months collected	Location by county**
73	**P. resinosus* Schrad. ex Fr.	Sept.	5, 8, 11, 15
74	**P. schweinitzii* Fr.	Aug., Oct.	8, 11
75	**P. tomentosus* Fr.	Aug., Sept., Nov.	8, 20
76	**P. versicolor* L. ex Fr.	Sept., Oct.	8, 10, 16
77	*P. zonatus* Fr.	June, Oct.	3, 11
78	**Poria* sp.	May–July	2, 3, 16
79	*P. incrassata* (B. & C.) Curt.	Oct.	10
80	**Trametes* sp.	July, Nov.	5
81	*T. malicola* Berk. & Curt.	July	12
82	**Boletinus pictus* Pk.	Aug.	10
83	**B. porosus* (Berk.) Pk.	July	5, 6, 10
84	*Boletus* sp.	July–Oct.	1, 4, 8, 10, 16
85	**B. edulus* Bull. ex Fr.	Aug.	2, 10
86	**B. felleus* Bull.	July–Sept.	1, 5, 10, 12, 18
87	**B. granulatus* L. ex Fr.	Oct.	14
88	**B. luteus* L. ex Fr.	July–Sept.	2, 5, 10, 12, 16
89	*B. mirabilis* (Murr.) Singer	July	17
90	**B. punctipes* Peck	Aug.	8
91	*B. retipes* B. ex C.	Aug., Sept.	2, 10
92	**B. scaber* Bull. ex Fr.	Aug.	8
93	**B. subaureus* Fr.	July	5
94	*Strobilomyces strobilaceus* (Scop. ex Fr.) Berk.	July	1
95	*Suillus* sp.	Oct.	10
96	*S. americanus* Peck	Aug.	2
97	*Agaricus abruptibulbus* L. ex Fr.	Sept., Oct.	8, 10
98	*A. campestris* L. ex Fr.	June	10
99	*Amanita* sp.	Sept., Oct.	10, 11, 16, 17
100	*A. fulva* (Schaeff.) ex Secr.	Sept.	2
101	*A. muscaria* (L.) Fr.	Aug.–Oct.	2, 5, 6, 11, 16, 17
102	*A. phalloides* Fr.	June–Aug.	2, 10
103	*A. verna* (Fr.) Quél.	July–Sept.	8, 16
104	*Armillaria* sp.	Nov.	21
105	**A. mellea* (Vahl.) Quél.	Oct., Nov.	10, 16, 20, 21
106	*A. zelleri* Seaver	Nov.	20
107	*Claudopus nidulans* Fr.	Sept.	5
108	*Clitocybe* sp.	July–Sept.	1, 2, 10, 11
109	*C. caespitosa* Bres.	July, Aug.	1, 10
110	*C. candida* Fr.	Aug.	10
111	*C. illudens* Schw.	Sept.	2, 16
112	*Collybia* sp.	Sept.	2, 8, 16
113	*C. velutipes* (Curt.) ex Fr.	May, Sept.	16, 21
114	*Coprinus atramentarius* (Bull. ex Fr.) Fr.	May, July, Oct.	10, 16
115	*C. comatus* Fr.	June, Sept., Oct.	8, 16
116	*C. micaceus* Fr.	June	10
117	*C. quadrifidus* Fr.	July	9
118	*Cortinarius* sp.	July, Aug., Sept.	2, 8, 12, 16
119	*Cylindrocarpon radicicola* (Jacq.) Quél.	May	19
120	*Entoloma* sp.	Aug.	2
121	*E. graynum* Pk.	Oct.	16
122	*E. sericatum* (Britz.) Sacc.	Sept.	2
123	*Hypholoma velutinum* (P.) ex Fr.	July	10
124	*Lactarius* sp.	July–Oct.	1, 2, 3, 5, 9, 10, 11, 12, 16
125	*L. auranticus* Fr.	Sept.	2
126	*L. chrysorheus* Fr.	July, Sept.	2, 6
127	*L. insulsus* Fr.	July	7
128	*L. vellereus* Fr.	Sept., Oct.	2, 10
129	*Lepiota* sp.	Oct., Nov.	10, 20, 21
130	*L. naucina* (Fr.) Quél.	Sept.	16
131	*L. procere* (Scop. ex Fr.) Quél.	Oct.	11
132	*Marasmius* sp.	Sept.–Nov.	5, 10, 11, 16, 21
133	*M. rotula* (Scop.) Fr.	June, Oct.	11, 16
134	*Myccana* sp.	Sept.	2
135	*M. leajana* Berk.	Sept.	2
136	*Panaeolus* sp.	Oct.	16
137	*Panus stypticus* Fr.	June, Sept.	2, 3
138	*Paxillus atrotomentosus* (Batsch.) Fr.	Sept.	15
139	*Pleurotus ostreatus* (Jacq. ex Fr.) Quél.	Sept.–Nov.	2, 16, 20
140	*P. porrigenes* (Pers.) Gill.	June	3
141	*P. ulmarius* (Bull. ex Fr.) Quél.	June	3
142	*Pluteus magnus* Quél.	Oct.	10
143	*Russula* sp.	July, Sept., Oct.	2, 5, 8, 10, 11, 16
144	*R. amygadaloides* Kauff.	Aug.	10
145	*R. atropurparea* (Krombh.) Maire	July	5

TABLE 1. (CONTINUED)

Collection No.	Fungus species	Months collected	Location by county**
146	*R. borealis* Kauff.	Aug.	10
147	*R. emetica* Fr.	Aug.	2
148	*R. virescens* Fr.	Aug.	2, 10
149	*Tricholoma* sp.	Sept.	1, 2, 5, 11, 12, 16
150	*T. personatum* (Fr.) Quél.	Sept.	16
151	*Volvaria bombycina* (Schaeff.) Fr.	June	10
152	*Dictyophora duplicata* (Bosc. ex Fr.) Firch.	Sept.	11, 16
153	*Phallus impudicus* L.	June, July	16
154	*Scleroderma* sp.	Nov.	21
155	*S. arenicola* Pers.	Oct.	16
156	*S. aurantium* Pers.	Sept.	11
157	*Nidularia* sp.	Nov.	21
158	*Bovista* sp.	Sept.	2
159	*B. nigriscens* Pers.	Nov.	21
160	*Clavatia maxima* Pers.	July, Sept.	16
161	*Chandroderma* sp.	Oct.	10
162	*Lycoperdon* sp.	Sept., Oct.	11, 12
163	*L. gemmatum* Batsch.	Sept.	2, 16
164	*L. perlatum* Pers.	Sept., Nov.	2, 20, 21
165	*L. pyriforme* Pers.	July, Sept., Oct.	5, 16
166	*Secotium agaricoides* (Czern.) Hollos.	Sept.	16
167	*Geaster triplex* Jungh.	Sept.	5, 17
168	*Dacrymyces deliquescens* (Bull.) Duby	June	3
169	*Tremella* sp.	Sept.	2
170	*T. latescens* Pers.	Sept.	2
171	*T. reticulata* (Berk.) Farlow	July, Sept.	5, 16
172	*Sarcoscypha* sp.	July, Oct.	2, 10
173	*S. coccinea* (Bull.) Fr.	July	10

*Indicates fungi considered important to the timber industry in Wisconsin (Newman 1919).
**Numbers under "Location by County" refer to numbers on Fig. 1

TABLE 2. RELATIONSHIPS OF THE INSECTA AND THE FAMILIES OF FUNGI.

Fungal Family	No. species fungi found	No. lots	Lots with insects	% lots with insects
Cantharellaceae	4	19	10	52.6
Clavariaceae	11	20	13	65.0
Fistulinaceae	2	26	18	69.2
Hydnaceae	5	10	3	30.0
Meruliaceae	2	4	0	00.0
Thelephoraceae	5	7	4	57.1
Polyporaceae	51	167	104	62.3
Boletaceae	15	54	40	74.7
Agaricaceae	54	178	105	58.9
Phallaceae	2	5	2	40.0
Sclerodermataceae	3	3	0	00.0
Nidulariaceae	1	1	0	00.0
Lycoperdaceae	9	19	8	42.0
Geastraceae	1	6	2	33.3
Dacrymycetaceae	1	1	0	00.0
Tremellaceae	3	5	1	20.0
Pezziaceae	2	3	3	100.0

FAUNAL CHECK-LIST

Listed here are all the animals obtained. The numbers refer to the "Collection Number" given in Table 1.

ACARINA (Mites)

Acaridae: *Tyrophagus putrescentiae*—108
Belbidae: *Belba* sp.—44
Camisiidae: *Camisia* sp.—68
Caraboididae: Undetermined—43
Ereynetidae: Undetermined—169
Galumnidae: *Galumna* sp.—49
Oribatulidae: *Scheloribates* sp.—19
Parasitidae: Undetermined nymphs—43, 108, 112, 113, 124, 134, 139, 128
Ologamasus sp.—44
Pergamasus sp.—10
Zerconidae: *Zercon* sp.—50

ARACHNIDA (Spiders)

Agelenidae:—1
Araneidae:—2, 17, 46, 116
Clubionidae:—2, 18, 139
Dictynidae:—2, 17, 57, 62
Gnaphosidae:—32
Hahiidae:—undetermined
Linyphiidae:—15, 37
Lycosidae:—17
Micryphantidae:—9, 32, 46, 167
Pisauridae:—55
Salticidae:—17
Theridiidae:—9, 17, 37, 38, 55, 57, 69
Thomisidae:—9, 17, 34, 50

PHALANGIDA (Daddy-long-legs)

Undetermined:—17, 40, 74, 124

CHILOPODA (Centipedes)

Geophilidae: *Geophilus* sp.—25
Lithobiidae: *Nadabius* sp.—38
Neolithobius mordax Koch—99
Paitobius sp.—2

DIPLOPODA (Millipedes)

Julidae: *Cylindroiulus* sp.—46, 129
C. caeruleocinctus (Wood)—113
Ophyiulus pilosus (Newport)—25, 99
Nemastomatidae: *Nopoiulus* sp.—113

GASTROPODA (Snails)

Anguispira alternata (Say)—17, 27
Deroceras laeve (Müller)—10
D. reticulatum (Müller)—2
Euconulus chersinus (Say)—17, 62
Vallonia parvula (Sterki)—2, 50, 142, 162
Zonitoides nitidus (Müller)—17, 42, 46, 50, 84

INSECTA (Insects)

BLATTARIA
Blattidae: *Parcoblatta* sp.—undetermined

COLEOPTERA
Anobiidae: *Catorama semibistriata* Mance—37
Lasioderma serricorne (Fabricius)—9, 63, 84, 129
Anthribidae: *Euparius marmoreus* Oliver—37, 38, 46, 65
Carabidae: *Agonium* sp.—2
Carabus vinctus Weber—undetermined
Pterostichus sp.—5
Chrysomelidae: *Gastroidea polygoni* (Linnaeus)—undetermined
Ciidae: *Ceracis sallei* Mellie—17, 31, 32, 37, 75, 164
C. singularis (Dury)—32, 62, 164
C. thoracicornis (Ziegler)—17, 31, 37
Cis americanus Mannerheim—17, 38, 62, 139
C. fuscipes Mellie—17, 25, 31, 32, 37, 50, 65
C. levettei (Casey)—36, 37, 38, 50, 62, 66
C. subtilis Mellie—17, 32, 37, 38, 65
Dolichocis manitoba Dury—17, 38, 50
Malacocis brevicollis (Casey)—32, 37, 38, 50, 63
Octotemnus laevis (Casey)—17, 31, 32, 38, 50, 73, 81
Rhopalodontus americanus Lawrence—36, 57, 62, 124, 143
Sulcacis curtulus (Casey)—32, 37, 38, 50
Cryptophagidae: *Toramus pulchellus* LeConte—139
Cucujidae: *Ahasverus advena* (Waltl)—undetermined
Curculionidae: *Sitophilus oryzae* (Linnaeus)—99
Elateridae: Undetermined—86, 122, 124, 144
Endomychidae: *Lycoperdina ferruginea* LeConte—162, 164, 165

ODONATA—36

ORTHOPTERA

Locustidae:—75

PLECOPTERA

Taeniopteryx nivilas Fitch—32

THYSANOPTERA

Cryptothrips rectangularis Hood—76
Hoplothrips sp.—46, 53
H. major Hood—53, 76
Haplothrips subtilissimus Haliday—100

Roles of the Fauna

Complete ecological communities have formed within the macrofruiting bodies of the fungi, with organisms adopting the same roles and exhibiting the same interrelationships as found on broader scales elsewhere in our environment. The roles range from that of the chance visitor (mycetoxene) to total dependence on the fruiting body for development (mycetobiont). An intermediate role is played by the mycetophile which can develop on or in a fruiting body but is not restricted to it. In addition there are parasites and predators and microorganisms present, all maintaining an intricate balance within the fruiting bodies.

INSECTA

BLATTARIA—In most cases roaches are apparently simply visitors.

COLEOPTERA—Many beetles have been associated in the past with various kinds of fungi and 18 families were encountered in the Wisconsin forms examined. With a few exceptions, the beetles preferred woody bracket fungi. Members of the Endomychidae, Elateridae, Erotylidae and Melandryidae exhibited a preference for the soft-bodied Cantharellaceae, Boletaceae and Agaricaceae. Their presence in such fungi perhaps may be accounted for by the fact of more moisture in these microhabitats than in the brackets or puffballs. The staphylinids, which were both mycetophagic and predators, did not discriminate between kinds of fungi, possibly because their presence depended on available prey. Ciids were definitely associated with heart-rot causing fungi and destroyed much of the fruiting bodies with which they were associated. The ostomid, *Thymalus fulgidius* Erickson, was also extremely efficient in destroying sporophores, especially those of *Daedalea unicolor*.

COLLEMBOLA—The literature and ecological associations of Collembola with fungi were reviewed by Graves (1960). Spring-

tails are common inhabitants of fungi and have caused considerable damage in commercial mushroom beds (Austin 1933; Maynard 1951). They were common inhabitants of many of the fungal types collected, being especially abundant in older brackets.

DIPTERA—It has been generally known for more than 150 years that many varieties of flies were in some manner associated with fungi. In 1839 Dufour conducted an extensive study of dipteran-fungal associations (Buxton, 1960). In 1841 Canzanelli described life-cycles for some fungus-feeding flies and two species of Sciaridae were reared on mushroom mycelia (Thomas, 1929). However, even today very little is really known about these insects, their specific biologies and the types of associations they enter into with the fungi; even their taxonomy is not well worked out.

This order was the most ubiquitous in the present study. Fourteen families of flies were reared from most of the fungus species. With the exception of the Ciidae (Coleoptera), fly larvae appeared to effect the greatest destruction of their hosts. Even when they occurred in relatively tough, leathery brackets the destruction was noticeable. Most of the flies encountered were at least mycetophiles, with several tipulids, mycetophilids, platypezids, chloropids and scatopsids being mycetobionts. In most cases the life cycles of the flies have become adjusted to fit with the life-span of the fungal fruiting bodies. For example, several of the fungus gnats (mycetophilids) completed their entire development in from two to three weeks, that being the life-span of the mushroom fruiting body in which they were developing. Apparently in some instances rapid decline of the sporophores was associated with microorganisms introduced by the insects.

HEMIPTERA—The true bugs have been considered as chance visitors to fungi. Some were predacious, e.g., anthocorids, nabids and reduviids and appeared to be preying upon fungal inhabitants. Others such as *Aradus* sp. and *Fulvius brunneus* (Provancher) were fungus feeders and may be completely dependent on the fungus for survival.

HOMOPTERA—The single cicadellid encountered was a visitor.

HYMENOPTERA—The Hymenoptera formed an integral part of the fruiting body community. They parasitized mycetophages and helped to keep their populations under control. *Meteorus betulini* Mason (Braconidae) was found parasitizing *Thymalus fulgidius* Erickson (Ostomidae: Coleoptera). *Aspilota* sp. (Braconidae) seemed to utilize phorid flies as hosts, as did *Synaldis acutidens* Fischer. The ants appeared to be merely visitors.

LEPIDOPTERA—Members of this order, as a group, have not been considered common fungus inhabitants, though some au-

thors have found a few associated with fungi (Rehfous 1955; Forbes 1923; Pielou 1966a, 1966b, 1968; Crumb 1956). However, with the exception of the geometrid, the Lepidoptera encountered appeared to be at least mycetophiles.

ODONATA—This was strictly a visitor.

PLECOPTERA—The plecopteron in a fungus was probably a chance visitor.

THYSANOPTERA—Several species of thrips have been reported as being fungus feeders (Graves, 1960). A few are predacious, but those observed during this study were feeding on the plants. They were associated with relatively old, partially decayed brackets in both wet and dry conditions.

CHILOPODA

This group of arthropods occasionally occurs in fungi and they have been considered to be predacious (Williams, 1928).

DIPLOPODA

Diplopods are known to occur occasionally in fungi, being usually saprophagous or herbivorous (Williams, 1928). Incidentally, all the millipedes encountered had been introduced from Europe.

GASTROPODA

Snails are usually considered adventitious in fungal fauna. Six species were found but their roles in the microhabitats are unknown. They appeared to scar the surfaces of soft brackets after which small flies (midges, drosophilids) laid eggs in the areas involved.

ACARINA AND ARACHNIDA

Spiders and mites form an important part in the fauna on fungi. The predatory spiders find readily available prey of many kinds, so it is not surprising that several families were encountered. Many mites are phytophagous and others parasitic.

FOOD WEBS

The fungal habitat supports a highly complex community exhibiting intricate food relationships. Attempts to portray food interrelationships are usually incomplete because of a lack of data, and those shown here form no exception. Figs. 2 and 3 illustrate partial food webs occurring in wood fungi and soil fungi respectively. The food webs diagrammed are based primarily on the associations encountered during this study.

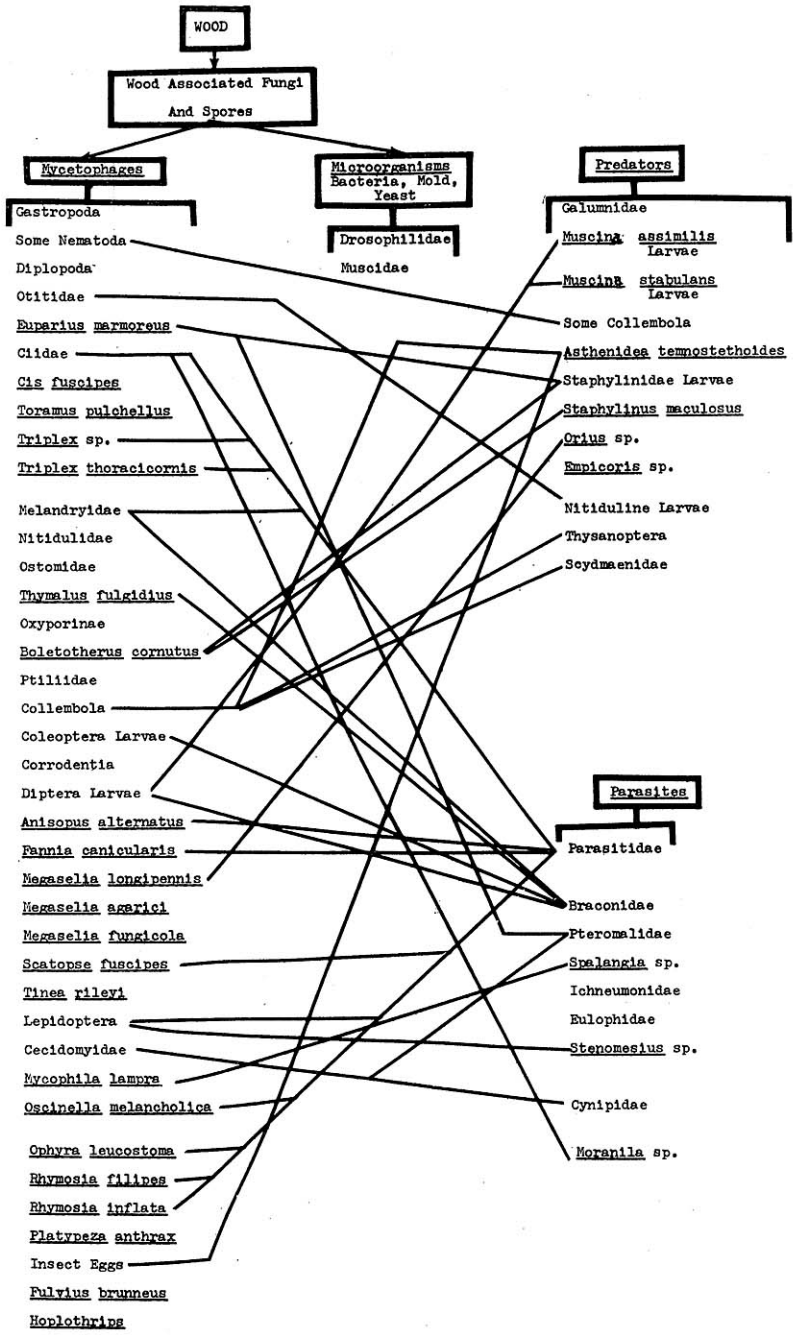

FIGURE 2. A partial food web for communities from wood associated fungi.

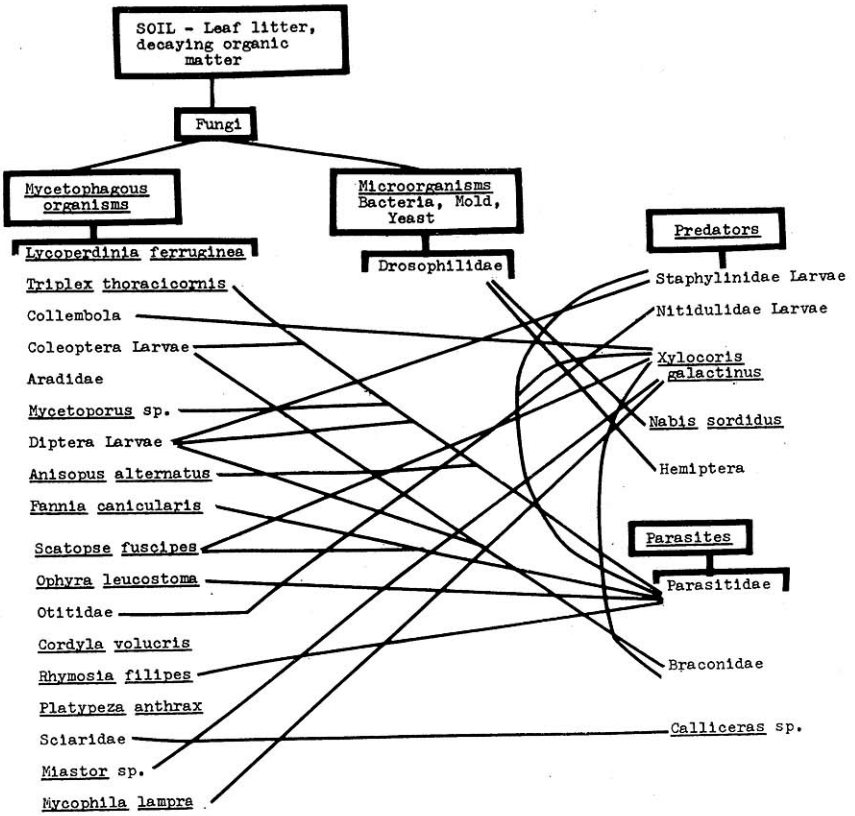

FIGURE 3. A partial food web for communities associated with soil fungi.

The wood substrate forms the basal portion of the food web for wood-associated fungi. It is from this substrate that the fungi draw their nourishment and eventually fruit. Their fruiting bodies and spores then comprise the second level of the food web and are the substrate which supports the faunal community. Fungus feeders utilize the mycelia and spores. These animals are in turn preyed upon by various predators and parasitized by mites and Hymenoptera. A secondary level is also formed by microorganisms growing in a fruiting body which in turn are fed upon by organisms sheltering in the fungus and which serve as hosts and prey for parasites and predators. This same kind of picture may be developed around soil fungi, except that the basal substrate is formed by soil, leaf litter, etc.

SUCCESSIONAL STAGES

Ecological conditions within a fungal fruiting body do not remain static throughout the life span of the fruiting body. Graves (1960) provided a scheme for classifying the successional stages of the conk microsere. The results obtained here support his scheme, which worked well for the woody, bracket type of fungal fruiting body. However, it did not apply to softbodied forms which have a very short life span. In these, it appeared that most of the organisms had already entered by the time the fruiting body was ready to sporulate. From the collections examined it appeared that only parasites and predators moved into the fruiting bodies after sporulation had begun.

The stages occurring in soft fruiting bodies could be divided as follows: Stage 1—early development, prior to sporulation; Stage II—period of sporulation; Stage III—period of liquefaction and decomposition.

During Stage I females seek out the fruiting bodies for oviposition. During this stage there may also be some initial larval development. During Stage II fly larvae complete their development and enter the pupal stage. Beetles may also complete most of their development during this time, but at a slower rate than the flies. At this point many insects appear to leave the fruiting bodies to pupate in the soil or leaf litter in the vicinity of the fruiting bodies. During Stage III the fruiting body is completely destroyed and many of the flies and beetles which had pupated emerge. These successional stages in softbodied fungi may succeed one another with extreme rapidity and the entire process be completed in a matter of two to three weeks. Collembola, parasites, predators and chance visitors can be found during both Stages II and III.

Not only did the fungal fauna change with the condition of the fruiting body and the species of fungus involved, but it also changed with the time of year in which the fruiting bodies were collected. This is exemplified in Fig. 4 which depicts the seasonal changes in fauna for 183 fruiting bodies of *Daedalea confragosa* taken from the same collection site in Sauk County. The numbers indicate the relative abundance of each organism during the months involved. As shown, different orders become dominant at different times, and within orders there is a succession of species. While the successions appear to be quite definite, they are subject to a large number of meteorological, physical, chemical and biological factors which it is not possible to analyze at the present stage of the investigation or indeed without the aid of numerous, well-controlled experiments directed toward that end. The study of such successional series would be very important in choosing insects for biological control programs. In all probability a series

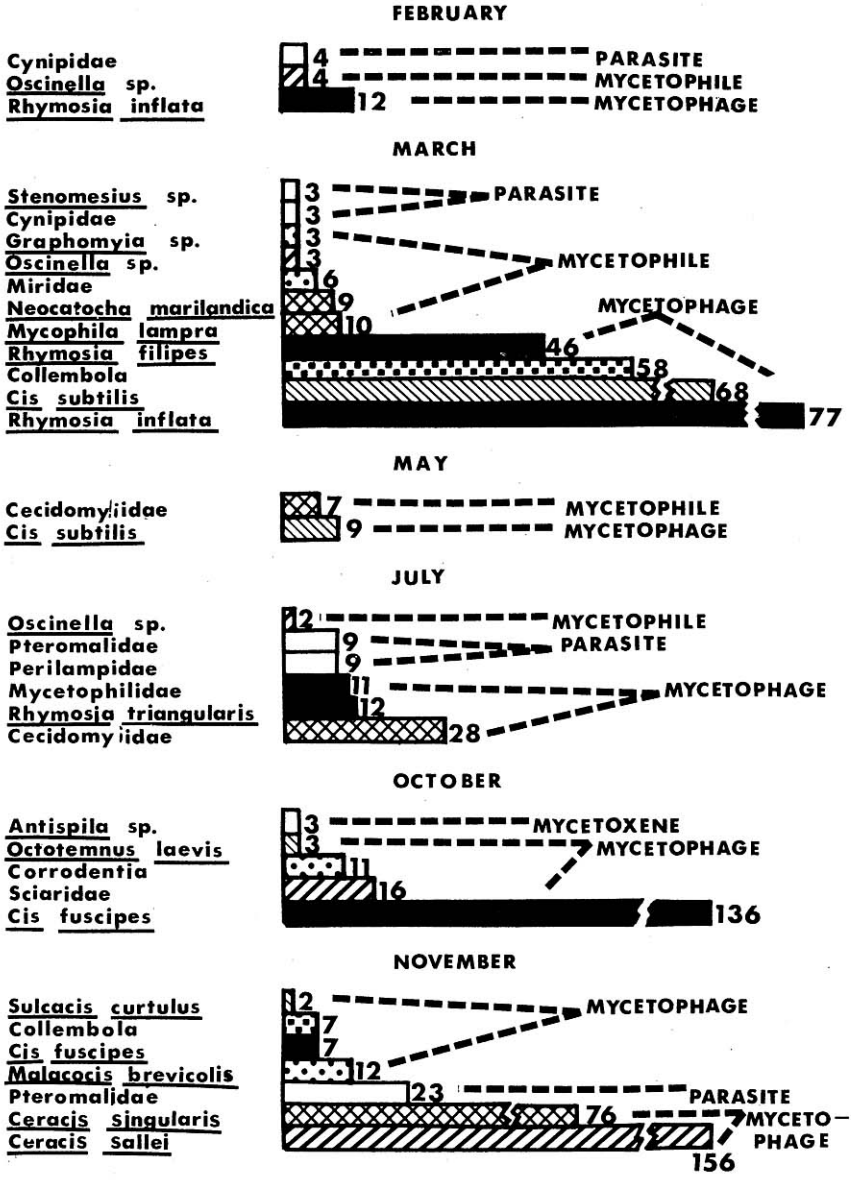

FIGURE 4. Faunal succession in fruiting bodies of *Daedalea confragosa*. (Based on 183 fruiting bodies).

of insects, active at different times of the year within Stage I for soft-bodied forms and Graves' Stages I and II for bracket fungi would be needed.

CONCLUSIONS

Fungal fruiting bodies form complete and highly complex ecological communities. Several groups of insects showed potential as possible biological control agents for some timber destroying fungi and should be studied in greater detail. These include Ciidae, Ostomidae (especially *T. fulgidius*), Tenebrionidae (especially *B. cornutus*), Drosophilidae, Muscidae and Mycetophilidae. Detailed studies of faunal successions related to stages of decay of the fruiting bodies and to season of the year should be conducted.

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