

REVIEW OF PEST ARTHROPODS RECORDED FROM COMMERCIAL MUSHROOM FARMS IN AUSTRALIA

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Abstract

Twenty-six arthropod species (nine Diptera, ten Acari, seven Collembola) are confirmed as mushroom pests in Australia. The data is based both on specimens in collections and published records. The species include one new record for Australia, *Bradysia difformis* Frey, 1948 and one new record for Tasmania, *Lycoriella ingenua* Frey, 1948. The latter was already known from the Australian mainland. Sixteen potential or past mushroom pests (six Diptera, two Acari, four Collembola), that occur in Australia but have not been found on commercial mushroom beds here, are also listed as well as three predatory mite species known to occur on edible mushrooms. Six records of incorrect and dubious identifications are noted. Distributional data and the deposition of voucher material are given for each species as well as brief notes of the economic effect of each species. Nearly all the species listed have cosmopolitan or near cosmopolitan distributions. Because the specific identity of some recorded specimens is not certain, a new survey of pests of commercial mushroom farms is recommended. Many species were economically damaging in the past but improved hygiene and growing techniques on farms have reduced their pest status to low or negligible.

P. Greenslade & A. Clift (2004). Review of pest arthropods recorded from commercial mushroom farms in Australia. *Australasian Mycologist* 23 (3): 77–93.

Introduction

Rapid air transport and international trade agreements have facilitated an increased international trade in horticultural produce with a short shelf life. Consumer taste in Australia has also broadened over the last twenty years with the development of an international cuisine resulting in a demand for a wider range of exotic foods including edible fungi. As a result, the local mushroom industry, both growers and importers, have expressed a desire to import species that are currently not on the Australian Quarantine and Inspection Service's (AQIS) permitted list. This brings with it a parallel increase in the need for quarantine surveillance of these commodities at ports of entry to prevent accidental entry of pest species, including invertebrates, which are not already established in Australia. To facilitate this process, an authoritative and verifiable list of Australian pests is needed so that correct quarantine management can be applied at the border. This paper provides an authoritative list of Australian pests prepared by collecting all records from the old and scattered literature and checking the published records against reliably identified specimens in collections when possible.

The list of pest species for commercially grown edible mushrooms in Australia given here is the first such list available for this commodity and summarises twenty years of work on the crop, mainly carried out in the NSW State Department of Agriculture (now Department of Primary Industry). Some new and unpublished records are included, as well as a brief summary of biological information, including the damage inflicted on edible fungi, for each species. The list also provides distributional data for each species within Australia and elsewhere as far as it is known. It should be pointed out that as many of the old records are of specimens collected sometimes as long as fifty years ago, a number of species, particularly Collembola, are no longer an economic problem to mushroom growers. This is because pasteurisation of compost is invariably now carried out and in other ways hygiene has improved enormously in all growing systems in Australia.

No taxonomic decisions are made here. The nomenclature used is based on the most recent published revision or catalogue. Identifications are only accepted if made by reliable authority and voucher material deposited in a recognised institution. Where identification is doubtful and specimens cannot be found for verification,

qualifications are made in the text. The names included are those that have been used for the Australian fauna and more complete synonymies are not always included. Some cosmopolitan species that occur in Australia, and are recorded as feeding on cultivated mushrooms but in countries other than Australia, have been included as they are potential mushroom pests in this country. Dubious identifications are included for completeness as are predatory mites, as their presence is an indication that food resources for them are available in the form of other invertebrates.

Abbreviations

Countries

UK—United Kingdom

USA—United States of America

States

NSW—New South Wales

SA—South Australia

Collections

ANIC—Australian National Insect Collection (Canberra, ACT)

ASCU—Agricultural Scientific Collections Unit, NSW Department of Primary Industries (Orange, NSW)

ELC—Evert Lindquist collection, Agriculture & AgriFood Canada (Ottawa, Canada)

NHML—H. Krczal collection, Hungarian Natural History Museum (Budapest, Hungary)

SAMA—South Australian Museum (Adelaide, SA)

DPIWE—(Tasmanian) Department of Primary Industry, Water and Environment collections (New Town, Tasmania)

ZMH—Zoological Institute and Zoological Museum of the University of Hamburg (Hamburg, Germany)

Taxonomists

AC—A. Clift

BH—B. Halliday

PG—P. Greenslade

BL—B. Loudon

CHECK LIST OF SPECIES

COLLEMBOLA

Clift (1978b, 1979) records two species of Collembola on cultivated mushrooms, one white and one slate grey. The former is probably *Onychiurus folsomi* and the latter, one of the species of hypogastrurid listed below.

Hypogastruridae

Ceratophysella armata (Nicolet, 1841)

Hypogastrura (Ceratophysella) armata (Nicolet, 1841)

Australian records from edible fungi: NSW (Conroy *et al.* 1966).

Other records of feeding on edible fungi: Hussey *et al.* (1969), Kim & Hwang (1996), Thron (1974), White (1982).

Voucher specimens from edible fungi: ASCU now identified as cf. *Ceratophysella denticulata* Bagnall (PG).

Edible fungi hosts: *Lentinula edodes*, *Pleurotus ostreatus*, *Agaricus* spp.

Extralimital distribution: Europe.

Remarks: specimens assigned to *H. armata* have probably all been misidentified (Greenslade 1994).

Ceratophysella armata is restricted to Europe and does not occur in Australia. The specimens of this species recorded from Australia (Cleland 1934, Conroy *et al.* 1966) and other countries outside Europe are probably referable to *C. denticulata* (Bagnall), *C. gibbosa* (Bagnall) or *C. engadinensis* Gisin.

Ceratophysella engadinensis (Gisin, 1949)

Australian records from edible fungi: NSW (PC, new record, North Ryde, mushrooms, 25.viii.1936).

Other records of feeding on edible fungi: none.

Voucher specimens from edible fungi: ASCU.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: not common in cultivated mushrooms.

Ceratophysella denticulata (Bagnall, 1941)

Australian records from edible fungi: NSW (Greenslade *et al.* 2002, Sydney, on mushrooms 10.ix.1936, North Ryde, iii.1978, PG, new record, ex mushrooms, det. Womersley).

Other records of feeding on edible fungi: none found.

Voucher specimens from edible fungi: SAMA.

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: near cosmopolitan.

Remarks: common commercial mushroom pest.

Hypogastrura manubrialis (Tullberg, 1869)

Australian records from edible fungi: NSW (PG, new record, beside mushrooms 4.ii.1936).

Other records of feeding on edible fungi: Hussey *et al.* (1969).

Voucher specimens from edible fungi: SAMA.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: more common in pastures in Australia.

Hypogastrura vernalis (Carl, 1901)

Australian records from edible fungi: NSW (PG, new record, in mushroom bed, Sydney, 8.i.1936).

Other records of feeding on edible fungi: none found.

Voucher specimens from edible fungi: ASCU.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: more common in agricultural land and domestic gardens.

Xenylla mucronata Axelson, 1903

Australian records from edible fungi: not recorded on cultivated mushrooms.

Other records of feeding on edible fungi: damaging cultivated mushrooms in the UK (Hussey *et al.* 1969, White 1982).

Voucher specimens from edible fungi: n.a.

Edible fungi hosts: commercial mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: the Australian (Western Australian) record of this species by Womersley (1939) is doubtful (Greenslade 1994).

Xenylla welchi Folsom, 1916

Australian records from edible fungi: not recorded on cultivated mushrooms.

Other records of feeding on edible fungi: damaging cultivated mushrooms in Italy (Ferrari 1971).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: *Psalliota* Fr. (*Agaricus* sp.). [*Psalliota* is a suppressed name for *Agaricus*.]

Extralimital distribution: near cosmopolitan.

Remarks: widespread in southern Australia but not found on cultivated mushrooms (Greenslade 1994).

Onychiuridae

Onychiurus ambulans (Linnæus, C., 1758): Gervais, 1841

Subspecies *inermis* Ågren, 1903

Australian records from edible fungi: NSW (Conroy *et al.* 1966).

Other records of feeding on edible fungi: none.

Voucher specimens from edible fungi: none found.

Edible fungi hosts: ?*Agaricus* sp.

Extralimital distribution: cosmopolitan (if correctly identified).

Remarks: almost certainly a misidentification. These specimens were possibly *Onychiurus folsomi* (Schäffer, 1900) or *Protaphorura encarpata* (Denis, 1931) that occur commonly in rotting straw and other moist, decaying plant material.

Onychiurus folsomi (Schäffer, 1900)

Australian records from edible fungi: NSW (PG, new record, West Ryde, 27.iii.1978, leg. AC).

Other records of feeding on edible fungi: none found.

Voucher specimens from edible fungi: ASCU.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: abundant in worm beds, horticultural situations and greenhouses. Recorded by Clift (1978b, 1979) as 'white springtails'.

Brachystomellidae*Brachystomella platensis* Najt and Massoud, 1974

Australian records from edible fungi: Greenslade *et al.* (2002).

Other records of feeding on edible fungi: none found.

Voucher specimens from edible fungi: SAMA.

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: South America.

Remarks: more common in improved pastures. This species was previously identified as *Brachystomella parvula* Schäffer, 1896 (Cleland 1934, Womersley 1939).

Isotomidae*Proisotoma minuta* (Tullberg, 1871)

Australian records from edible fungi: not recorded on cultivated mushrooms.

Other records of feeding on edible fungi: Hiol *et al.* (1995), Hussey *et al.* (1969), Hopkins (2004), White (1982).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: *Suillus luteus* and cultivated fungi.

Extralimital distribution: cosmopolitan.

Remarks: a common species in Australia and elsewhere in rotting vegetation.

Proisotoma tenella (Reuter, 1895)

Australian records from edible fungi: determination confirmed PG (unpublished results 1999).

Other records of feeding on edible fungi: Hopkins (2004).

Voucher specimens from edible fungi: ASCU.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: collected only once in Australia in 1933, from possibly a single introduction and not established. Hopkins (2004) notes a slide in the NHML with specimens of *Proisotoma* collected from 'mushrooms' in Penrhyn, Bangor, North Wales. Most of the Collembola on the slide are *P. minuta*. However, mixed among them is at least one specimen of *P. tenella*.

Isotoma sp. indet.

Australian records from edible fungi: NSW det. confirmed PG (unpublished results, 1999).

Other records of feeding on edible fungi: n.a.

Voucher specimens from edible fungi: ASCU.

Edible fungi hosts: unknown.

Extralimital distribution: n.a.

Remarks: none.

Entomobryidae*Lepidocyrtus cyaneus* Tullberg, 1871

Australian records from edible fungi: none on cultivated mushrooms.

Other records of feeding on edible fungi: Cave (1997), Christiansen & Bellinger (1998), Figueiredo & Mucci (1985), Kim & Hwang (1996), Thron (1974).

Voucher specimens from edible fungi: n.a.

Edible fungi hosts: *Lentinus edodes*, *Marasmius oreades*.

Extralimital distribution: near cosmopolitan.

Remarks: species identification not confirmed for Australia.

Lepidocyrtus lanuginosus Gmelin, 1790

Australian records from edible fungi: none on cultivated mushrooms.

Other records of feeding on edible fungi: Christiansen & Bellinger (1998), Figueiredo & Mucci (1985), Hussey *et al.* (1969).

Voucher specimens from edible fungi: n.a.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: near cosmopolitan?

Remarks: species identification not confirmed for Australia.

Lepidocyrtus sp. indet. and *Lepidocyrtus* sp. cf. *kukua* Christiansen & Bellinger, 1992

Australian records from edible fungi: NSW (PG, new record), Greenslade *et al.* (2002).

Other records of feeding on edible fungi: n.a.

Voucher specimens from edible fungi: ANIC.

Edible fungi hosts: *Agaricus bisporus*, *Pleurotus djamor*.

Extralimital distribution: unknown.

Remarks: this is an unpublished new record, leg. PG, det. PG (1998) still to be identified definitely to species.

INSECTA: DIPTERA: SCIARIDAE

Bradysia difformis Frey, 1948

= *Bradysia paupera* Tuomikoski, 1960

= *Bradysia agrestis* Sasakawa, 1978

Australian records from edible fungi: Tasmania (new record for Australia).

Other records of feeding on edible fungi: Menzel *et al.* (2003).

Voucher specimens from edible fungi: DPIWE.

Edible fungi hosts: cultivated mushrooms (*Agaricus bisporus*, *Agaricus brasiliensis*).

Extralimital distribution: Europe, North and South America, Japan.

Remarks: *Bradysia difformis* has not been recorded from Australia before. It is a common pest overseas of indoor plants, glasshouses and moist pastures as well as commercial mushroom houses. Identification of specimens from a Tasmanian mushroom farm and also from a pot plant at Kingston, Tasmania, was confirmed by F. Menzel (J. Smith 2004b).

Bradysia ocellaris (Comstock, 1882)

= *Bradysia tritici* (Coquillett, 1895)

Sciara tritici Coquillett, 1895

Australian records from edible fungi: NSW (AC, new record, Loudon, pers. comm.).

Other records of feeding on edible fungi: Brar & Sandhu (1990), Menzel *et al.* (2003).

Voucher specimens from edible fungi: ASCU (NSW) det. BL, DPIWE (Tasmania) (Semmens *et al.* 1992, det. AC and det. F. Menzel).

Edible fungi hosts: cultivated mushrooms (*A. bisporus*, *A. bitorquis*, *A. brasiliensis*, *A. brunnescens*, *Pleurotus cystidiosus*, *Pleurotus ostreatus* and *Auricularia* spp.).

Extralimital distribution: Africa, Europe, SE Asia, North and South America.

Remarks: synonymy by Menzel & Mohrig (2000). *Bradysia ocellaris* is not recorded in the ABRS catalogue of Australian Diptera (Bugledich 2004) but is listed by Semmens *et al.* (1992) in a checklist of Tasmanian insects as *B. tritici*. The 1992 Tasmanian record was based on specimens collected in a New Town glasshouse. Collis (pers. comm.) notes that the name is included in an unpublished key by Loudon. *Bradysia ocellaris* feeds on roots or stems and is a common pest of glasshouses and gardens, being also found in woodlands and on stream banks as well as in mushroom farms (Menzel *et al.* 2003). More recently, the species was recorded from Queensland (Menzel *et al.* 2003). The new record from Tasmania is from a mushroom farm at Huonville and identification was confirmed by Menzel (J. Smith 2004b).

Lycoriella agraria (Felt, 1897)

Sciara agraria Felt, 1897

Australian records from edible fungi: Vic. (Clift 1979).

Other records of feeding on edible fungi: Figueiredo & Mucci (1985).

Voucher specimens from edible fungi: identified by BL.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: Palearctic, Nearctic, Brazil.

Remarks: may no longer be present in Australia according to Clift (pers. comm.) quoted by Bugledich (2004). Alternatively, it may have been a misidentification in Clift (1979). According to J. Smith (2004a), this species may also be a synonym of *Lycoriella ingenua*.

Lycoriella castanescens (Lengersdorf, 1940)

= *Lycoriella auripila* sensu Freeman 1983 nec. Winnertz, 1867

= *Lycoriella agarici*, Loudon, 1978

Australian records from edible fungi: NSW (Clancy 1981a, Clift 1978a, 1979, 1983, 1986b, Clift & Larsson 1984, 1987, Clift & Toffolon 1981b, c, d, Loudon 1978).

Other records of feeding on edible fungi: Binns (1979).

Voucher specimens from edible fungi: ASCU (NSW) (*agarici* pinned and larvae in alcohol from fungi, one specimen labelled *agaricus*).

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: Europe, South Africa.

Remarks: Freeman (*in litt.*) identified the type series of *L. agarici* as *L. auripila*. Evenhius (1989) does not document this synonymy. The main character whereby Loudon separated *auripila* and *agarici* was on the colour of the halteres—fuscous black as opposed to brown. However, it has been shown subsequently (Menzel & Mohrig 2000), that this character is variable in this species. Freeman's (1983) description of *L. auripila* Winnertz actually refers to *L. castanescens*. This species was the dominant pest fly in mushroom houses until about 1985.

Lycoriella ingenua (Dufour, 1839)

= *Molobrus mali* Fitch, 1855

Lycoriella mali (Fitch, 1855)

= *Lycoriella solani* (Winnertz, 1871)

Sciara solani Winnertz, 1871

Australian records from edible fungi: NSW (Clift 1979, 1983, 1986a, b, 1993, Clift & Toffolon 1981b, c, Clift & Larsson 1984, 1987, Clift & Terras 2001), Tas. (new record) (Smith 2004).

Other records of feeding on edible fungi: Kielbasa & Snetsinger (1980).

Voucher specimens from edible fungi: ASCU (NSW) (pinned and alcohol collections of *solani* from cultivated mushrooms), DPIWE (Tas.).

Edible fungi hosts: commercial mushrooms.

Extralimital distribution: Nearctic, Europe, Hawaiian Is.

Remarks: synonymy confirmed by Menzel & Mohrig (2000) and Sinclair (2004). The identification of Tasmanian specimens was confirmed by F. Menzel (J. Smith 2004b). This species is the largest of the group and was first found at Bankstown (1984/5). It is a relatively recent introduction to Australia and replaced *L. castanescens*. It is now a major pest in NSW (Clift 1986b) and was common in commercial mushrooms in the Huon Valley, Tasmania in 2004 (J. Smith 2004b).

Lycoriella multiseta (Felt, 1897)

Australian records from edible fungi: Vic., NSW? (Clift 1979, Loudon 1978).

Other records of feeding on edible fungi: Figueiredo & Mucci (1985).

Voucher specimens from edible fungi: ASCU (in alcohol).

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: Nearctic, Brazil.

Remarks: possibly an incorrect identification by Clift (1979). This species was found on shiitake from Melbourne and also known from bat dung in Wombeyan Caves (BL, unpublished data). It is not a very serious pest and is a poor competitor compared with *L. ingenua*.

Drosophilidae

Drosophila funebris (Fabricius, 1787)

Musca funebris Fabricius, 1787

Australian records from edible fungi: none on cultivated mushrooms.

Other records of feeding on edible fungi: none found.

Voucher specimens from edible fungi: none found.

Edible fungi hosts: commercial mushrooms?

Extralimital distribution: cosmopolitan.

Remarks: common in wild-collected mushrooms. It has been collected in Australian mushroom houses, but not recently (Clift pers. comm.).

Cecidomyiidae: Lestremiinae

Heteropeza pygmaea Winnertz, 1846

Australian records from edible fungi: NSW (Clift 1978a, b, 1979, 1983, 1986a, b, Clift & Larsson 1985, Clift & Terras 1995b, Clift & Toffolon 1981b, Clift et al. 1980, Nair & Clift 1993).

Other records of feeding on edible fungi: White (1992).

Voucher specimens from edible fungi: Rydalmere, NSW ex mushroom culture det. BL (ASCU).

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: cosmopolitan.

Remarks: larvae persist in casing layer materials after composting, both in imported sphagnum peat and local sugar mill by-products. Diapausing pupae that are only killed by heating to 55°C for two hours have been recorded in imported sphagnum peat. Paedogenetic larvae are produced from these pupae (Clift 1986b).

Mycophila barnesi Edwards, 1938

Australian records from edible fungi: NSW (Clift 1978a, 1979, 1983, Clift & Terras 1995b, Clift et al. 1980, Nair & Clift 1993).

Other records of feeding on edible fungi: Hussey et al. (1969), White (1982).

Voucher specimens from edible fungi: Rydalmere, NSW ex mushroom culture (ASCU).

Edible fungi hosts: *Agaricus bisporus*, *Agaricus bitorquis*.

Extralimital distribution: near cosmopolitan.

Remarks: the most damaging cecidomyiid in Australia, damaging 90% of sporophores. Clift & Larsson (1985) misidentified this species as *Mycophila speyeri* (Barnes, 1926).

Henria psalliotae Wyatt, 1959

Australian records from edible fungi: NSW (Clift 1986b, Clift & Terras 1995b, Nair & Clift 1993).

Other records of feeding on edible fungi: Hussey et al. (1969), Lin & Ni (1974), White (1982).

Voucher specimens from edible fungi: specimens not found in ASCU but det. confirmed by M. Fletcher (A. Clift pers. comm.).

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: UK + ?Europe.

Remarks: first recorded in January 1984 in Oakville, NSW and has spread widely since that time. Larvae mine into the tissues of the mushroom and cannot be cleaned away by washing during the canning processes.

Phoridae

Megaselia halterata (Wood, 1910)

Australian records from edible fungi: NSW (Clift 1978a, b, 1979, 1983, 1986a, b, 1993, Clift & Larsson 1987, Clift & Terras 2001, Clift & Toffolon 1981b).

Other records of feeding on edible fungi: Hussey et al. (1969), Hussey (1961, 1981), Hussey & Wyatt (1962), Thron (1974).

Voucher specimens from edible fungi: ASCU (numerous collections from cultivated mushrooms).

Edible fungi hosts: *Agaricus [brunnescens] bisporus*, *Agaricus bitorquis*, *A. campestris*.

Extralimital distribution: Europe, New Zealand, South Africa, USA.

Remarks: recorded Clift (1978b, 1979); identification confirmed Disney (1993); a minor pest (Clift 1986b).

Megaselia scalaris (Loew, 1866)

Australian records from edible fungi: none found.

Other records of feeding on edible fungi: Nickolls & Disney (2001).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: *Pleurotus sajor-caju*, *Agaricus bisporus*.

Extralimital distribution: near cosmopolitan.

Remarks: habitat normally decaying animal material (CSIRO 1991). Introduced to Casey Station in the Antarctic in rotten eggs (Nickolls & Disney 2001). Found on commercially grown *Pleurotus* in India (Johal & Disney 1994) and *Agaricus* in Iran.

Sphaeroceridae*Pullimosina heteroneura* (Haliday, 1836)*Leptocera heteroneura* Haliday, 1836**Australian records from edible fungi:** none found.**Other records of feeding on edible fungi:** Hussey *et al.* (1969).**Voucher specimens from edible fungi:** none found.**Edible fungi hosts:** cultivated mushrooms.**Extralimital distribution:** near cosmopolitan.**Remarks:** the normal habitat is compost, manure, decaying organic matter; it tends to be found in commercial compost yards.*Tapeigaster annulipes* Macquart, 1847= *Dryomyza cingulipes* Walker**Australian records from edible fungi:** McAlpine & Kent (1982).**Other records of feeding on edible fungi:** none.**Voucher specimens from edible fungi:** AM.**Edible fungi hosts:** *Agaricus campestris*.**Extralimital distribution:** none.**Remarks:** larvae have been reared in the laboratory on the fruiting body of a mushroom, but the species probably does not occur on commercial mushrooms naturally.*Tapeigaster nigricornis* (Macquart, 1851)*Sciomyza nigricornis* Macquart, 1851*Tapeigaster marginifrons* Bezzi, 1923**Australian records from edible fungi:** McAlpine & Kent (1982).**Other records of feeding on edible fungi:** none.**Voucher specimens from edible fungi:** AM.**Edible fungi hosts:** *Agaricus* sp., *Boletus* sp.**Extralimital distribution:** none.**Remarks:** larvae have been reared in the laboratory on the fruiting body of a mushroom, but the species probably does not occur on commercial mushrooms naturally.**Lepidoptera: Noctuidae***Sandava scitisignata* (Walker, 1862)**Australian records from edible fungi from edible fungi:** SA? (Common 1990).**Other records of feeding on edible fungi:** none.**Voucher specimens from edible fungi:** SAMA?**Edible fungi hosts:** cultivated mushrooms.**Extralimital distribution:** none.**Remarks:** Macfarland (1979) notes that he bred this species on edible mushrooms and that it probably normally feeds on fungi on bark.**ARACHNIDA: ACARI**

Note: Clift (1978a, 1979) records 'undescribed species of *Pygmephorus*, *Caloglyphus* and *Histiostoma*', in 1978b he records a 'Gamasidae' and in 1983, unidentified species of *Rhizoglyphus* and *Tyrophagus*. The specimens referred to are now considered to belong to already described species as listed below.

Prostigmata

The following four families, Microdispidae, Scutacaridae, Siteroptidae and Pygmephoridae, all belong in the superfamily Pygmephorooidea, but the systematics of the group at both family and genus level are currently artificial and unstable (Kaliszewski & Rack 1986). For this reason, the systematic arrangement found in the world checklist of mites (Amrine *et al.* 2004) is not always followed.

Microdispidae*Microdispus (Premicrodispus) lambi* (Krczal, 1964)*Brennandania lambi* (Krczal, 1964)*Pygmephorus lambi* Krczal, 1964

Australian records from edible fungi: NSW (Clift 1983, 1986a, b, 1993, Clift & Larsson 1987, Clift & Terras 2001, Clift & Tofflon 1981a, b, Nair & Clift 1993).

Other records of feeding on edible fungi: Wicht (1970).

Voucher specimens from edible fungi: ASCU, NHML.

Edible fungi hosts: *Auricularia auricula*, *Hericium erinaceus*, *Tremella fuciformis*; *Agaricus bisporus* and *Agaricus bitorquis*.

Extralimital distribution: Australia, China, ?New Zealand, Spain.

Remarks: recorded as *?Pygmephorus A* in Clift (1979). The original description records the type from New Zealand (Auckland) although this is an error for Australia (NSW) according to Clift (pers. comm.). Kaliszewski & Rack (1986) redescribed this species based on a large series of females, males and immatures from mushroom cultures at Rydalmer, NSW. *Microdispus lambi* is a major pest of mushrooms in Australia as it feeds directly on the mushroom mycelium. Females are phoretic on phorid flies such as *Megaselia halterata*. It is included in Halliday's (1998) Australian mite catalogue.

Scutacaridae

Scutacarus australiensis Mahunka, 1967

Australian records from edible fungi: NSW (rare) (Clift & Terras 2001).

Other records of feeding on edible fungi: Binns (1979).

Voucher specimens from edible fungi: ASCU (several collections of unidentified *Scutacarus* sp. from mushroom beds).

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: none.

Remarks: found in compost. Females are phoretic on phorid and sciarid flies. They are also dimorphic, the phoretic form possessing claspers distally on the tibiotarsus. Halliday (1998) records this species from Australia only. Clift & Terras (2001) recorded *Scutacaropsis* sp. cf. *baculitarsus* Mahunka, 1968 but this record was of *Scutacarus australiensis*.

Siteroptidae

Pediculaster mesembrinae (Canestrini, 1880)

Siteroptes mesembrinae (Canestrini, 1880)

Pygmephorus mesembrinae Canestrini, 1880

= *Pigmephorus americanus* Banks, 1904

Australian records from edible fungi: present in all States (Clift 1983, 1986a, Clift & Terras 1994, 1995a, Clift & Tofflon 1981a, b, Clift et al. 1996, Terras & Hales 1995, Nair & Clift 1993). Identification confirmed by G. Rack.

Other records of feeding on edible fungi: Hussey et al. (1969).

Voucher specimens from edible fungi: ASCU (several collections from mushroom farms).

Edible fungi hosts: *Agaricus bisporus* and *Agaricus bitorquis*.

Extralimital distribution: cosmopolitan including New Zealand (Martin 1978).

Remarks: recorded as *?Pygmephorus B* in Clift (1979). *Pediculaster mesembrinae* is not a primary pest of mushrooms, as it feeds preferentially on weed moulds in the crop and carries spores of *Trichoderma* in a pair of sporotheca located ventrally near the base of legs IV (Terras & Hales 1995). It is commonly found in baled straw and can survive in compost during pasteurisation, but its presence indicates that the compost is not selective for the mushroom mycelium (Clift & Terras 1994). It was recorded as *Pigmaeophorus americans* (sic.) by Conroy et al. (1966) and as *Pygmephorus* sp. by Clancy (1981a), but was recorded by Halliday (1998) as *Pygmephorus mesembrinae*.

Pygmephoridae

Pygmephorus allmanni Krczal, 1964

Microdispus allmanni (Krczal, 1964)

Australian records from edible fungi: NSW (Krczal 1964b).

Other records of feeding on edible fungi: Gurney & Hussey (1967).

Voucher specimens from edible fungi: only known from the type material (NHML, Krczal collection, Seaforth, NSW on 27.iv.1949, leg. Allmann).

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: Australia only.

Remarks: both this species and *M. lambi* were described by Krczal in the genus *Pygmephorus* in the same year (1964) but in different journals. Both species were sent to Krczal at different times by the same

collector, K. Lamb. Krczal (1964a, b) makes no comments in his descriptions about the relationship of or differences between these two species, although there are some differences in morphology according to the figures. *Pygmephorus allmanni* is known only from the type series and was described only from females. It may be a synonym of *M. lambi*, as females can be variable in this group.

Tarsonemidae

Tarsonemus myceliophagus Hussey, 1963

Luptarsonemus myceliophagus (Hussey, 1963)

Australian records from edible fungi: NSW (Clift *in litt.* 1993, Conroy *et al.* 1966 as 'Tarsonemid mites').

Other records of feeding on edible fungi: White (1982).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: USA, UK, New Zealand, Netherlands, Germany.

Remarks: the record of this species is new and the specific identification was confirmed by Eberhard (*in litt.*). This species is common on grasses in the Sydney region, but is now rare in mushroom cultivation as its presence indicates inadequate compost preparation.

Tarsonemus waitei Banks, 1912

Australian records from edible fungi: none.

Other records of feeding on edible fungi: Belczewski & Harmsen (1996).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: field mushrooms.

Extralimital distribution: near cosmopolitan.

Remarks: Halliday (1998) does not record this species from Australia, but Walter & Bryant (1998) have recorded it from south-eastern Australia. Kim *et al.* (1998) describe a related species, *Tarsonemus parawaitei* Kim, Qin & Lindquist from New Zealand and Australia. *Tarsonemus parawaitei* and *T. waitei* have been reared on fungi (*Trichoderma*) in culture and are believed to feed on fungi on fruits.

Eupodidae

Linopodes antennaepeps Banks, 1894

Australian records from edible fungi: NSW (Clancy 1981a (as '*Linopodes* sp.' and as close to this species)).

Other records of feeding on edible fungi: Hussey *et al.* (1969).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: Italy, UK, USA.

Remarks: the identity of specimens collected by Clancy has not been confirmed. *Linopodes* species are still present in mushroom cultivation but are not common. *Linopodes antennaepeps* is the only species in the genus recorded from Australia by Halliday (2001).

ASTIGMATA

Histiostomatidae

Histiostoma feroniarum (Dufour, 1839)

Anoetus feroniarum Dufour, 1839

Australian records from edible fungi: all States (Clancy 1981a (as *Histiostoma* sp.), Clift 1983, 1986a, Clift & Terras 1991, 1994, 1995a, Clift *et al.* 1996, Nair & Clift 1993).

Other records of feeding on edible fungi: Hussey *et al.* (1969).

Voucher specimens from edible fungi: ASCU (slide labelled *Histiostoma* sp. not further identified).

Edible fungi hosts: *Pleurotus ostreatus*, *Agaricus bisporus*, *Agaricus bitorquis* and *Lentinus edodes*.

Extralimital distribution: France, Italy, Korea Republic.

Remarks: this species can cause serious crop losses especially if red pepper mites are also present. It is commonly found in baled straw and can survive in compost during pasteurisation, but its presence indicates that the compost is not selective for the mushroom mycelium (Clift & Terras 1994). It is a vector of disease organisms and is also a pest of garlic and is found in sewage filter beds and house dust (Learner & Chawner 1998).

Histiostoma sapromyzarum (Dufour, 1839)

Australian records from edible fungi: none in cultivated mushrooms.

Other records of feeding on edible fungi: Boness (1968).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: cultivated mushrooms.

Extralimital distribution: virtually cosmopolitan.

Remarks: this species has only been recorded from cultivated mushrooms outside Australia, but it is present in Australia (Halliday 1998, 2000).

Acaridae

Rhizoglyphus echinopus (Fumouze et Robin, 1868)

Australian records from edible fungi on edible fungi: Clift (pers. comm. 1993).

Other records of feeding on edible fungi: Boness (1968), Fan & Zhang (2003).

Voucher specimens from edible fungi: none found.

Edible fungi hosts: *Pleurotus sajor-caju* and *Pleurotus ostreatus*.

Extralimital distribution: probably cosmopolitan.

Remarks: commonly a pest of bulbs and only seen twice in mushroom houses in sixteen years collecting (Clift pers. comm.) but this identification has not been confirmed. This species is also recorded from rice straw and other plant material (Fan & Zhang 2003). A closely related species, *Rhizoglyphus robini* Claparède, 1869, another cosmopolitan bulb pest occurring in Australia, has been recorded on mushroom compost in New Zealand (Fan & Zhang 2003).

Tyrophagus putrescentiae (Schrank, 1871)

Australian records from edible fungi: NSW (Clancy 1981a determined as 'Tyroglyphid mites' and as 'probably' this species), Conroy *et al.* 1966.

Other records of feeding on edible fungi: Osborne (1893).

Voucher specimens from edible fungi: ASCU (cf. det. E. Schicha from mushroom compost, NSW).

Edible fungi hosts: *Agaricus* sp. and *Volvariella* sp.

Extralimital distribution: China, USA, UK, India, France, Australia, Netherlands, Italy, Egypt, Iraq, Germany, Zimbabwe, Chile, Russia, India; probably cosmopolitan.

Remarks: these mites feed on the mycelium and sporophores. They cause damage by burrowing small irregular pits in stalks and caps and cause shrunken caps and brown rusty spots on the mushrooms. The species can cause complete destruction of the young button mushrooms and is most abundant in the upper layer of compost.

Cosmoglyphus oudemansi Zakhvatkin, 1937

Caloglyphus mycophagus sensu Womersley nec (Mégnin)

Australian records from edible fungi: NSW (Clancy 1981a as '*C. mycophagus*').

Other records of feeding on edible fungi: Hussey *et al.* (1969).

Voucher specimens from edible fungi: none available.

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: near cosmopolitan.

Remarks: the identification of this species has not been confirmed and the reference to *C. mycophagus* in Clancy (1981a) may refer to *S. berlesei* Michael.

Sancassania berlesei (Michael, 1903)

Tyroglyphus berlesei Michael, 1903

= *Tyroglyphus mycophagus* Mégnin, 1874 *sensu* Berlese, 1891

Australian records from edible fungi: NSW (Clift unpublished record), Clancy (1981a).

Other records of feeding on edible fungi: Hussey *et al.* (1969).

Voucher specimens from edible fungi: ASCU (cf. det. E. Schicha).

Edible fungi hosts: *Agaricus bisporus*.

Extralimital distribution: cosmopolitan.

Remarks: not a common species in mushroom houses. It attacks hyphae and sporocarps of all sizes.

Mesostigmata: Macrochelidae

Macrocheles robustulus (Berlese, 1904)

= *Macrocheles coprophila* Womersley, 1942

Australian records from edible fungi: NSW (PG, new record from mushroom beds).

Other records of feeding on edible fungi: n.a. as it is a predator.

Voucher specimens from edible fungi: ANIC (det. BH).

Edible fungi hosts: n.a. as it is a predator.

Extralimital distribution: Italy, Israel.

Remarks: Clancy (1981a) records an undetermined species of *Macrocheles* from commercial mushroom farms in NSW. Animal dung is the most common habitat for this species.

Parasitus sp. indet. imm.

Australian records from edible fungi: NSW (PG, new record from mushroom beds).

Other records of feeding on edible fungi: n.a. as it is a predator.

Voucher specimens from edible fungi: ANIC (det. BH).

Edible fungi hosts: n.a. as it is a predator.

Extralimital distribution: unknown.

Remarks: this is an unpublished record, leg. PG, det. BH (1998).

Proctolaelaps sp. nov.

Australian records from edible fungi: NSW (Nair & Clift 1993).

Other records of feeding on edible fungi: n.a. as it is a predator.

Voucher specimens from edible fungi: ELC.

Edible fungi hosts: n.a. as it is a predator.

Extralimital distribution: restricted to Australia.

Remarks: the Australian species is new and undescribed (E. Lindquist, pers. comm.). It feeds on the eggs and females of siteroptid mites and, although the genus is considered predominantly predatory, it also feeds on the fungus genus *Trichoderma*.

Table 1. Currently confirmed pests of Australian commercial mushrooms.

Higher classification	Species name	Common name
Collembola	<i>Ceratophysella denticulata</i>	Mushroom Springtail
	<i>Ceratophysella engadinensis</i>	Springtail
	<i>Hypogastrura manubrialis</i>	Mushroom Springtail
	<i>Hypogastrura vernalis</i>	Purple scum Springtail
	<i>Onychiurus folsomi</i>	Rootfeeding Springtail
	<i>Brachystomella platensis</i>	Springtail
	<i>Lepidocyrtus</i> spp. indet.	Springtail
Insecta: Diptera	<i>Lycoriella castanescens</i>	Mushroom Sciarid
	<i>Lycoriella ingenua</i>	Mushroom Sciarid
	<i>Lycoriella multiseta</i>	Mushroom Sciarid
	<i>Bradysia difformis</i>	Black Fungus Gnat
	<i>Bradysia ocellaris</i>	Black Fungus Gnat
	<i>Heteropeza pygmaea</i>	White Mushroom Cecid
	<i>Mycophila barnesi</i>	Yellow Mushroom Cecid
	<i>Henria psalliotae</i>	Gall Midge
	<i>Megaselia halterata</i>	Scuttle Fly
Acari	<i>Microdispus lambi</i>	Australian Mushroom Pygmy Mite
	<i>Scutacarus australiensis</i>	Scutacarid Mite
	<i>Pediculaster mesembrinae</i>	Red Pepper Mite
	<i>Tarsonemus myceliophagus</i>	Tarsonomid Mite
	<i>Linopodes antennaeipes</i>	Long Legged Mushroom Mite
	<i>Histiostoma feroniarum</i>	Bacterial Feeding Mite
	<i>Rhizoglyphus echinopus</i>	Bulb Mite
	<i>Tyrophagus putrescentiae</i>	Mould Mite
	<i>Cosmoglyphus oudemansi</i>	Acarid Mite
	<i>Sancassania berlesei</i>	Acarid Mite

Table 2. Potential pests of commercial mushrooms in Australia.

Class/Order	Species name	Common name	Comments
Collembola	<i>Xenylla welchi</i>	Springtail	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
	<i>Proisotoma minuta</i>	Springtail	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
	<i>Proisotoma tenella</i>	Springtail	May no longer be present in Australia
	<i>Isotoma</i> sp. indet.	Springtail	Found beside not in mushroom bed
Insecta: Diptera	<i>Pullimosina heteroneura</i>	Short Heel Fly	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
	<i>Lycoriella agraria</i>	Mushroom Sciarid	May have been a misidentification or may not now be present in Australia
	<i>Megaselia scalaris</i>	Scuttle Fly	A pest of mushrooms overseas and present in Australia but yet found not on commercial mushrooms
	<i>Tapeigaster annulipes</i>	Sun Fly	Not a natural host for the species
	<i>Tapeigaster nigricornis</i>	Sun Fly	Not a natural host for the species
	<i>Drosophila funebris</i>	Vinegar Fly	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
Insecta: Lepidoptera	<i>Sandava scitisignata</i>	Moth	Not natural host for the species
Acar: Prostigmata	<i>Tarsonemus waitei</i>	Peach Bud Mite	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
Acar: Astigmata	<i>Histiostoma sapromyzarum</i>	Bacterial Feeding Mite	A pest of mushrooms overseas and present in Australia but not on commercial mushrooms
Acar: Mesostigmata	<i>Macrocheles robustulus</i>	Macrochelid Mite	Predator
	<i>Parasitus</i> sp.	Parasitid Mite	Predator
	<i>Proctolaelaps</i> n. sp.	Ascid Mite	Predator

Discussion

The total number of arthropod species recorded from commercial mushroom beds in Australia is twenty-six (nine Diptera, ten Acari, seven Collembola). They are listed in Table 1. Sixteen other potential or past mushroom pests (six Diptera, two Acari, four Collembola and a moth) that occur in Australia but have not been found on commercial mushroom beds here, are listed in Table 2 together with three predatory mite species known to occur on edible mushrooms. Six records of incorrect and dubious species identifications are noted in Table 3. All the Australian host records are from *Agaricus bisporus*, *A. bitorquis* or *Pleurotus* sp. Other speciality mushroom hosts are not represented as no surveys have been carried out on these species as this industry has only recently been developed. It is expected that the number of pests would rise once this is done.

Transportation from place to place of invertebrate pests is common on both the commodity and the media such as peat moss or compost. Even media described as sterile can contain mites and flies with an inert resting or phoretic stage. For instance, peat moss from Russia (Sakhalin Is. near Vladivostoc), where average winter temperatures are -10°C carried cecidomyiids to Australia, and compost from New South Wales carried flies to Queensland (Clift pers. comm.). Another documented example of transport of pests is of inert stages of *Mycophila speyeri* from Singapore to Japan in imported spawn of *Pholiota nameko* (Yukawa 1996).

Invertebrates that are associated with commercial fungal fruit bodies tend to be widely distributed with good dispersal mechanisms (they are either winged or have a phoretic stage), possess an ability to breed rapidly and their life histories often include inert resting stages (pupa or egg or, for mites, a hypopus) that are resistant to heat, cold and dry conditions and so easily transported. This is an advantage as the mushroom host is a temporary resource and decays rapidly. These traits are characteristic of *r* strategy species (Greenslade 1993). Most of the species listed here have a cosmopolitan distribution and were introduced to Australia except for *M. lambi*. They also tend to be fairly non-specific as far as edible fungal hosts are concerned and are able to colonise and breed on a great variety of fleshy fungi.

It is clear from the unconfirmed records and few reliably identified voucher specimens in collections that an Australia-wide survey of mushroom pests with expert taxonomic involvement is indicated.

Table 3. Species of doubtful or incorrect identification found in commercial mushroom beds.

Higher classification	Species name	Common name	Comments
Collembola	<i>Ceratophysella armata</i>	Springtail	Incorrect identification
	<i>Xenylla mucronata</i>	Springtail	Doubtful record from Australia
	<i>Onychiurus ambulans</i>	Springtail	Incorrect identification
	<i>Lepidocyrtus cyaneus</i>	Springtail	Species identification uncertain
	<i>Lepidocyrtus lanuginosus</i>	Springtail	Species identification uncertain
Acaria	<i>Pygmephorus allmanni</i>	Pygmephorid Mite	Possibly a synonym of <i>Microdispus lambi</i>

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