Distribution and status of Psocoptera infesting stored products in Australia

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Abstract

In Australia, infestations of Psocoptera in stored products, especially *Liposcelis* species, appear to have become more frequent in recent years. Changes in pest control and inspection practices, together with seasonal factors such as poor grain condition because of adverse harvesting conditions, have been implicated in this.

There is no up-to-date survey of the distribution and status of these insects in stored products in Australia. With the collaboration of State grain handling authorities, and departments of agriculture, health and primary industries, samples of psocids were collected and identified from around the country to gain an insight into the species composition, status and distribution of the psocid fauna of stored products in Australia.

A total of 11 species was found from three genera. Most frequently encountered were *Liposcelis bostrychophila* Badonnel, *Liposcelis decolor* (Pearman) and *Liposcelis entomophila* (Enderlein) (Psocoptera: Liposcelidae). *Lachesilla quercus* (Kolbe) (Psocoptera: Lachesillidae) was recorded for the first time as a regular inhabitant of grain storage facilities. *L. quercus*, *Liposcelis rufa* Broadhead and *Liposcelis brunnea* Motschulsky were recorded in Australia for the first time.

Introduction

Psocoptera or psocids have traditionally been viewed as scavengers and mould feeders and of little importance as pests of stored products. However, from time to time, psocids, especially *Liposcelis* species, have been found infesting grain in very large numbers.

There is little published information on the distribution and status of psocids in stored products in Australia. Champ and Smithers (1965) recorded some 15 species from 8 families from farms and grain stores in Queensland. Watt (1965) records *Liposcelis bostrychophila* Badonnel as infesting and damaging wheat in New South Wales. Since that time, changes to methods used in Australia to control storage pests have occurred, from the almost universal admixture of insecticides into grain to the current reliance on fumigation with much reduced structural spraying. Such changes are likely to have had an impact on the psocids present. A fresh look is needed.

Methods

Psocids were collected from stored grain, grain products and from other stored dried animal and plant material. Samples were obtained from all mainland states of Australia except Northern Territory. Samples were collected on an *ad hoc* basis both by the author and as a result of requests to state bulk handling authorities, Queensland Department of Primary Industries, Western Australia Department of Agriculture, Queensland Department of Health, various CSIRO divisions and others. Specimens obtained were cleared and mounted and then identified using the keys of Lienhard (1990) and Mockford (1991). Material collected has been lodged in the Australian National Insect Collection.

Species Distribution

Psocoptera were found associated with stored products in all states from which samples were collected. Locations from which specimens were found are plotted on maps (Fig. 1) and the habitats in which they were found are given in Table 1.

A total of 11 species were identified belonging to three genera: *Liposcelis, Lachesilla* and *Lepinotus*. Psocids were found infesting stored products throughout their post harvest life, from the farm, in storage, through to shops, offices and domestic premises. They were also found as pests in museums and herbaria.

Liposcelis species

The majority of infestations found were of *Liposcelis* species. Eight species were identified, three of which appear to be widely distributed in Australia (Fig. 1, Table 1). All eight species found have been recorded from stored products somewhere in the world (Lienhard 1990).

The most frequently encountered species were *Liposcelis bostrychophila, Liposcelis decolor* (Pearman) and *Liposcelis entomophila* (Enderlein). *L. bostrychophila* was the most widely distributed species and was found in the largest number of habitats (Fig. 1, Table 1). It was the dominant species infesting material in shops, offices, museums, and domestic premises. *L. decolor* was found only in bulk handling authority and farm stores and was more frequently encountered in samples from South and Western Australia than from the eastern states. In grain stores, *L. bostrychophila* and *L. decolor* were most often found, usually in small numbers, infesting residues in store buildings and related grain handling equipment. However, extremely heavy infestations of *L. decolor* and / or *L. bostrychophila,* which formed the majority of pest biomass present, were found during the autumn and winter months of 1993 in bulk stored barley in South Australia, wheat in Western Australia and lupins in New South Wales. Associated with these infestations were large accumulations of dead and living insects on walkways above infested cells and in tunnels below.

L. entomophila was found mostly at coastal or near coastal locations in farm and bulk handling authority stores. Populations were found infesting store structures and machinery, residues, disused grain bins and on one occasion, a bulk of barley. During 1993, at least one shipment of grain infested with this species was rejected at export from Australia.

Other *Liposcelis* species were recorded from single locations. *L. corrodens* (Heymons) was found in residues in the now disused Sydney grain terminal. A very heavy infesta-

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Table 1. Habitats in which psocopteran species were found in Australia

Species	Bulk Handling Authority stores											
	Barley	Wheat	Sorghum	Lupins	Residues	Store structures	Farm stores	Feed mills	Flour mills	Museums, herbaria	Hospitals, offices, shops	Houses
L. bostrychophila	X	X	X	X	X	X	X		X	X	X	X
L. decolor	X					X	X					
L. entomophila	X				X	X	X					
L.brunnea	X	X										
L. corrodens					X							
L. paeta								X				
L. mendax						X						
L. rufa											X	
Lachesilla quercus						X						
Lepinotus spp.							X					

tion of *L. paeta* Pearman was discovered in sorghum at a feed mill at Ayr, North Queensland. *L. mendax* Pearman were found in an empty grain shed at Maimuru (lat. 34:14S, long. 148:23E) near Young, New South Wales. Two species, *Liposcelis brunnea* and *Liposcelis rufa* appear not to have been recorded in Australia before. *L. brunnea* Motschulsky was found infesting wheat and barley in a silo at Streaky bay (lat. 32:48S, long. 134:12E), South Australia and *L. rufa* Broadhead was discovered in a house in Canberra, ACT, on wood recently purchased from a timber merchant in the city.

Lachesilla quercus (Kolbe)

In nature, species of *Lachesilla* browse on algae, moulds etc. which grow on dying leaves of trees; *L. quercus* can, for example, be attracted to a tree by breaking branches to produce prematurely senescent foliage (New 1987). *Lachesilla* are winged insects that can fly quite well and probably travel long distances by being carried by the wind (New 1987). *Lachesilla pedicularia* (L.) is known from grain stores and domestic situations in Europe and North America (Mockford 1991; Obr 1978). A species of *Lachesilla* was found associated with peanuts at Kingaroy, Queensland, Australia (Champ and Smithers 1965).

Lachesilla quercus apparently has not been previously recorded in Australia. This species is not known as a regular inhabitant of grain storage in its native Europe and Asia. However, it has been found in the garage of a house in Prague on stored boards (Obr 1978) and was once found in a flour warehouse in Florida USA on jute sacks imported from Pakistan (Prof. E. L. Mockford, per. comm.). It has been found over the last two seasons living on the machinery and fabric of silos and empty grain sheds at Northampton, Geralton, Kwinana, Albany and Esperance in coastal south west Australia, sometimes in large numbers, browsing on minute particles of edible dust present on beams and walls. It does not appear to penetrate bulks of grain. This insect produces large amounts of silk webbing which quickly becomes covered with dust, under which they live, breed and feed. Large numbers of dead insects can accumulate together with deposits of very fine black faeces. In the stores in which it has been found, which are kept very clean, it is usually the only insect present. Populations appear to fluctuate wildly from one month to the next but so far infestations have been found in stores from early winter to mid-summer.

Under laboratory conditions at 27°C, 75% r.h., on a brown rice and dried yeast based diet, this species was found to breed continuously and have a high rate of reproduction. It is therefore very capable of taking advantage of conditions in stores when they are favourable.

Lepinotus species

Populations of *Lepinotus reticulatus* (Enderlein) and *Lepinotus inquilinus* Heyden were found on farms in far south western Western Australia. These species are also known from stores and houses in Europe and North America (Mockford 1991; Obr 1978) and on farms in southern Queensland (Champ and Smithers 1965).

Discussion

Psocids, especially *Liposcelis* spp., are widely distributed in Australia and are common and widespread inhabitants of grain stores. They were found in most places in which stored products are produced, stored and used, from the farm to the final consumer. Data collected so far provide only a sketchy picture and doubtless more species will be discovered, and those currently known will be found to have an even wider distribution. Single records of some species are likely to prove to be 'snapshots' of more widespread distributions.

All of the species found in this survey are probably introductions to Australia and have either cosmopolitan or extensive distributions worldwide. Australia has, and probably still is acquiring, these insects by trade and the movement of people and their effects. Their small size and unspecialised diet makes them ideal, inconspicuous candidates for such introduction. Well known pest species such as *Liposcelis bostrychophila, L. entomophila, L. decolor* and *L. paeta* are established in Australia.

Psocids were mostly found to be persistent pests in the structure of grain stores, feeding on often hard-to-find small deposits of residues. However, *Liposcelis* can penetrate whole bulks of grain in silos, leading to contamination with large and unacceptable quantities of living and dead insects. Piles of dead insects which form on walkways etc. are a very public statement of poor hygiene, a safety hazard (such deposits make walkways very slippery) and a potential food source for other insects such as *Trogoderma variabile* Ballion (Coleoptera: Dermestidae). What triggers off such population explosions remains unclear. What damage such numbers do to grain, especially to commodities such as malting barley and seed grain, has not yet been quantified although it could be expected to be extensive. *Liposcelis* species are known to be capable of attacking whole grains and have a preference for the grain germ (Watt 1965; McFarlane 1982; Rees and Walker

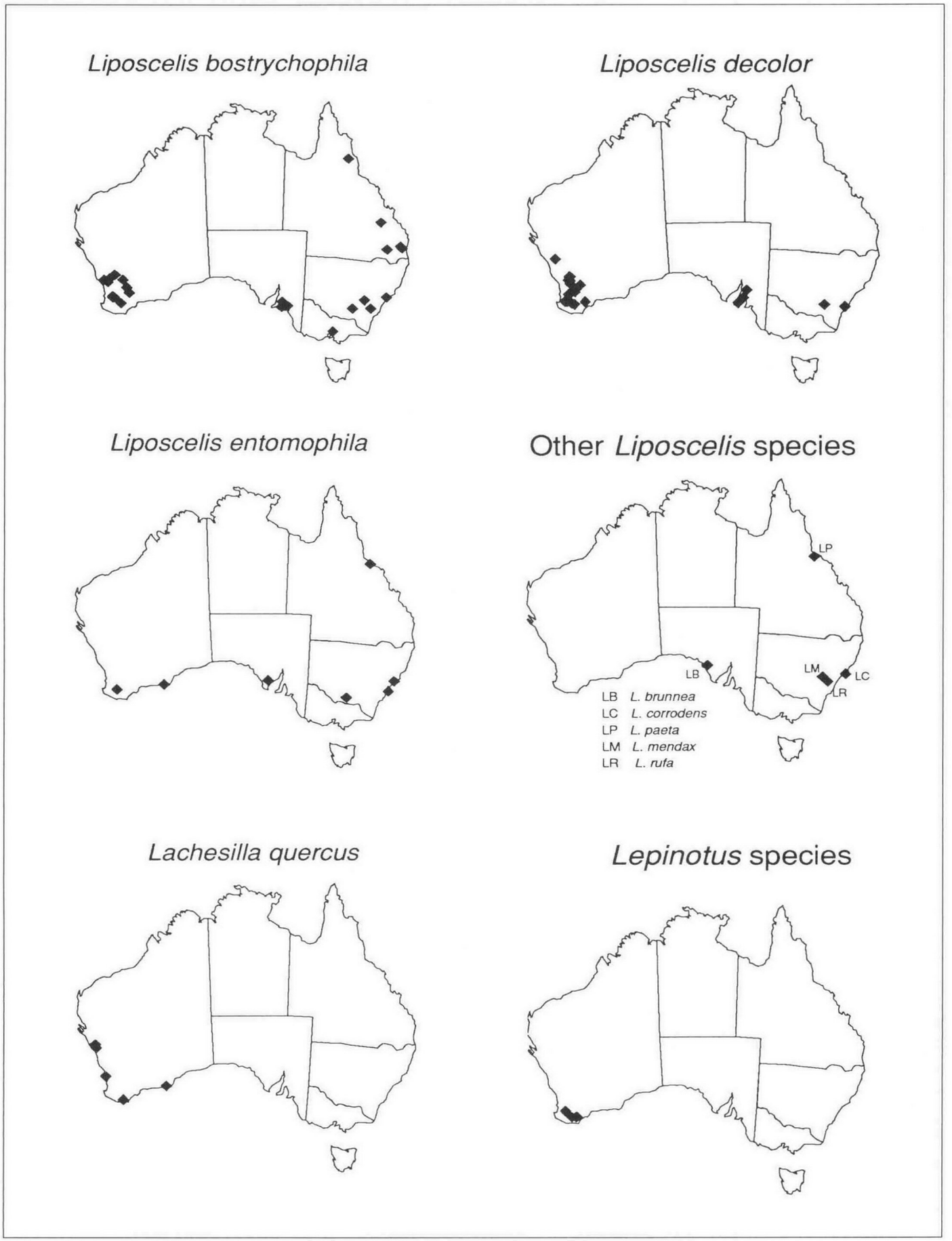

Fig. 1. Locations at which Psocoptera associated with stored products were found

1990). However, their presence in parcels of grain has already caused the rejection of at least one shipment at export, with all the attendant costs that entails.

The species that appears most widely distributed and found in the greatest variety of habitats is *L. bostrychophila.* In Australia it appears to be virtually the only species found in shops, offices, museums and domestic premises. This species, unlike the other *Liposcelis* species found, is parthenogenetic. An infestation can therefore start with a single egg or immature individual. In this way it is probably better able than others to become established in locations where infestable materials are kept and moved in small discrete batches (houses, museums etc.). In such places it is most likely to be introduced as a single individual or in very small numbers. In Europe, this species appears also to be the dominant species in domestic and retail premises (Lienhard 1983; Obr 1978; Turner and Maude-Roxby 1989).

More data may or may not confirm the observations that *L. decolor* is more widespread in the south west of Australia than in the eastern states or that *L. entomophila* is mostly confined to more humid coastal locations. However, in the case of the latter, *L. entomophila* is known to be the dominant psocid infesting stored rice in hot, humid areas of Java, Indonesia (Haines and Pranata 1982)

Optimum conditions for development of *Liposcelis* are about 30°C, 70–80% r.h., breeding will occur at 18–35°C; however, *L. paeta* is known to breed at temperatures up to 42°C. (Rees and Walker 1990). For long-term survival of populations, mean humidity should be more than about 58% r.h. (equivalent to a grain moisture content of 12–13%). Below this level, *Liposcelis* lose more water to the atmosphere than they gain from it (Knülle and Spadafora 1969). The very low day-time humidities in summer in much of Australia may not be sufficient to kill these insects if they can recuperate sufficiently during the cooler, more humid nights. Every grain storage facility contains many potential micro-environments (cracks, crevices, damp spots, basements, inside beams etc.) in some of which humidities remain much higher than ambient. In such places psocids could easily survive hostile conditions. During the autumn to spring storage season, ambient conditions become more humid and temperatures in many grain stores fall but not to levels that would prevent breeding taking place. During this time psocids are likely to range more widely than in summer and hence become more obvious as pests. Observations made during this survey suggest that this may be the case. In shops and offices, temperature and humidities are usually better regulated so may remain suitable for these insects all year round.

A number of factors may be important in the apparent increase in incidence of occurrence of these insects in Australia in recent years. The grain harvest in some seasons, such as 1992–93, can be affected by bad weather conditions during which a proportion of grain is dried and wetted several times before harvest. Such damaged grain is easier for any insect to attack than sound, dry grain. An increase in maximum wheat receival moisture content (12.5%) into bulk handling stores could also alter the incidence of these insects in such facilities.

Changes have also occurred in the use of insecticides. No longer is grain routinely sprayed with insecticide on intake into storage. In many stores, surface applications have also been discontinued or the chemical used changed in response to obligations to control other pests, notably *Trogoderma variabile.* There has been a reduction in the use of fenitrothion, an insecticide known to be effective against *Liposcelis* (Turner et al. 1991), in favour of other chemicals which may be less so. The discontinuance of surface spraying may be partly responsible for allowing the establishment of *Lachesilla quercus* in grain stores in Western Australia. Edible grain dust no longer contains insecticide residues as it would have done when grain was sprayed at intake, so is now available as food for psocids. Many stores infested with *L. quercus* can now be sealed for fumigation and have been painted with reflective white paint to help minimise solar heating of the air inside which would otherwise put pressure on the integrity of the seal. The reflective paint may be having the undesirable side-effect of allowing populations of *Lachesilla* to survive as the air inside is less likely to be heated to insecticidal temperatures than it would be if the store remained unpainted. *Lachesilla* appears to be especially able to survive in very clean stores. It probably uses the webbing it makes to catch its own food, such as edible dusts, from the air. Populations of this species will probably be found living in trees (its natural habitat) in nearby townships. This insect can fly and such populations could act as a continual source of re-infestation as conditions allowed. Indeed its relation, *L. pediculoria* is a seasonal migrant between natural habitats and buildings (Obr 1978). The arrival of 'new' insects such as this into storage is a reminder that the list of insects that attack stored products is not fixed and will change in response to many factors. A species such as *L. quercus,* being a surface feeder on dust and other edible material deposited on dead leaves, appears well adapted to life foraging on walls and machinery of a grain store.

As standards of commodity management improve, the status of various pests present will change. Pests which live mostly in bulks of grain are controlled by fumigation and basic levels of housekeeping. Other species, such as psocids, may survive such a regime in the smallest quantities of residues in ancillary parts of grain stores which are often missed. Populations probably move between natural habitats and domestic situations or commercial storage, for example, on clothing, pallets and packing material. Given the design of many facilities and the nature of working practices undertaken, the level of hygiene required to prevent the establishment of these insects is likely to be impossible or very difficult to achieve. Such populations should be monitored with the awareness that, especially in the case of *Liposcelis* spp., they can seriously infest whole bulks of grain. Standards of inspection and hygiene need to especially high in sensitive areas of storages, museums, and factories such as sample rooms, packing lines and long-term stores if infestations of these insects are to be avoided in such places.

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References

Champ, B.R. and Smithers, C.N. 1965. Insects and mites associated with stored products in Queensland. 1. Psocoptera. Queensland Journal of Agricultural and Animal Sciences, 22, 259–262.

Haines, C.P. and Pranata R.I. 1982. Survey of insects and arachnids associated with stored products in some parts of Java. In; Teter, N.C. and Frio, A.S. eds., Progress in grain protection—Proceedings of

the 5th annual grains post-harvest workshop, Changmai, Thailand 19–21 January 1982. SEARCA, Laguna, Philippines. 17–47.

Knülle, W. and Spadafora, R.R. 1969. Water vapour sorption and humidity relationships in *Liposcelis* (Insecta: Psocoptera). Journal of Stored Product Research, 5, 49–55.

Lienhard, C. 1983. Die Staubläuse der Region Zürich (Insecta : Psocoptera), Vierteljahrsschrift der Naturforschenden Gesellschaft in Zurich, 128, 115–129

Lienhard, C. 1990. Revision of the Western Palaearctic species of *Liposcelis* Motschulsky (Psocoptera : Liposcelidae). Zoologishe Jahrbuecher Abteilung fur Systematik Oekologie und Geographie der Tiere, 117, 117–174.

McFarlane, J.A. 1982. Damage to milled rice by Psocids. Tropical Stored Product Information, 44, 3–10.

Mockford, E.L. 1991. Psocids (Psocoptera). In: Gorham, J. R. ed. Insect and mite pests in food: an illustrated key. United States Dept. of Agriculture, Agriculture Handbook no. 655, 2, 371–402.

New, T.R. 1987. Biology of the Psocoptera. Oriental Insects, 21, 1–109.

Obr, S. 1978. Psocoptera of food-processing plants and storages, dwellings and collections of natural objects in Czechoslovakia, Acta Entomologica Bohemoslovaca, 75 226–242.

Rees, D.P. and Walker, A.J. 1990. The Effect of temperature and relative humidity on population growth of three *Liposcelis* species (Psocoptera: Liposcelidae) infesting stored products in tropical countries. Bulletin of Entomological Research, 80, 353–358.

Turner, B.D. and Maude-Roxby, H. 1989. The prevalence of the booklouse *Liposcelis bostrychophilus* Badonnel (Liposcelis, Psocoptera) in British domestic kitchens, International Pest Control, July/August 1989, 93–97.

Turner, B.D., Maude-Roxby, H. and Pike, V. 1991. Control of the domestic insect pest *Liposcelis bostrychophila* (Badonnel) (Psocoptera): an experimental evaluation of the efficiency of some insecticides. International Pest Control, November/December 1991, 153–157.

Watt, M.J. 1965. Notes on pests of stored grain *Liposcelis bostrychophilus* and *Sitophilus* spp. The Agricultural Gazette, November 1965, 693–696