

The effect of grain movement on *Liposcelis decolor* (Pearman), *Liposcelis bostrychophila* Badonnel (Psocoptera:Liposcelidae) and *Cryptolestes ferrugineus* (Stephens) (Coleoptera:Cucujidae) infesting bulk-stored barley

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Abstract

A trial was undertaken at Port Giles grain export terminal, South Australia, to determine to what extent *Liposcelis decolor* (Pearman), *Liposcelis bostrychophila* Badonnel and *Cryptolestes ferrugineus* (Stephens) infesting barley in a vertical silo cell were killed when the grain was moved mechanically to a new cell. During this process, samples were drawn at 10-minute intervals from three locations along the grain path. Numbers were recorded of adult insects in these samples. As a check, pitfall probe traps were placed in the grain both before and after moving.

Both genera were found distributed throughout the grain bulk before turning, with concentrations of psocids noted at both the grain peak and in the ducting leading to the conveyor belt. About one third of adult *Liposcelis* and less than one fifth of *Cryptolestes* present before turning survived the process, a level of mortality insufficient to give any practical level of control. Mortality caused by grain handling cannot be relied upon to control these insects in export shipments.

Introduction

Grain often needs to be moved within a storage complex, whether at receipt, at delivery, or for various other operational reasons. When stored in bulk, grain is typically kept in vertical cells in silos or in horizontal sheds or bunkers. Movement from one place to another involves mechanical handling by an often complex combination of conveyor belts, augers, bucket elevators and (sometimes) pneumatic systems. It is then often dropped from a height, into a ship, rail truck or cell etc.

During such movement, grain is subjected to mechanical shock, impact, vibration, shaking, centrifugal forces etc, which can prove fatal to insects present (Banks 1986). A number of studies have shown that mechanical handling of grain can cause high mortality among adults and larvae of a number of stored-product beetle pests. Cogburn et al. (1972) showed that more than 99% and 80% kill of adults or larvae, respectively, of *Rhyzopertha dominica* (Fab.) (Coleoptera: Bostrichidae), *Cryptolestes* spp. (Coleoptera: Cucujidae) and *Sitophilus oryzae* (L.) (Coleoptera: Curculionidae) were killed in wheat when passed from cell to cell by screw

conveyor, bucket elevator and two pneumatic conveyors. Bahr (1990) obtained the highest levels of kill with beetle species that spend all their lives between grains, such as *Oryzaephilus surinamensis* (L.) (Coleoptera: Silvanidae), rather than with species such as *Sitophilus* spp. which spend part of their lives within grains.

Dropping grain from a height also causes some mortality, Loschiavo (1978) showed that mortality of adult *Cryptolestes ferrugineus* (Stephens) (Coleoptera: Cucujidae) increased from about 5% with one fall of 14.1 m onto a steel plate to about 99% with 7 consecutive drops. Mortality was slightly reduced when the grain containing the insects was poured onto a bed of wheat rather than onto a steel plate. Mortality of both *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Sitophilus granarius* (Coleoptera: Curculionidae) treated in the same way was slight. However, quantitative observations on the survival of *Liposcelis* spp. during grain handling at a silo complex do not appear to have been made.

A heavy infestation of *Liposcelis decolor* (= *terricola*) Pearman and *Liposcelis bostrychophila* Badonnel (Psocoptera: Liposcelidae) was found in 2000 t of barley held in an open-topped concrete vertical cell at Port Giles grain terminal, South Australia. Also present was an obvious population of *Cryptolestes ferrugineus*. Specimens of psocids were identified to species using the keys of Mockford (1991) and Lienhard (1990). About 90% of specimens examined appeared to be *L. decolor*, the rest *L. bostrychophila*. An opportunity to observe the fate of this population arose when the grain was moved from one cell to others before pre-export fumigation. Operational staff at the terminal reported that while live psocids were sometimes seen in some parcels of grain they seemed to disappear by the time grain reached the ship-loading conveyor.

Methods

The barley used in this study had been taken into store in January 1993, about five months before these investigations. It was kept in an open-topped concrete vertical cell (no. 207), 32 m high and 10.7 m in diameter and fumigated at intake by pellet admixture of aluminium phosphide into the grain stream at cell loading.

Before moving the grain, an attempt was made to assess the distribution and density of insect populations present. Pitfall probe traps ('Probe trap' ex. Agrisence BCS Ltd) were inserted at three locations (one at each depth) at 0.5, 1, 2, and 4 m depth (Fig. 1). These traps were left in place for 24 hours before examination. Using a sampling probe, grain samples (ca. 120 g) were also taken from three locations at 0.5, 1, 2, 4, 6, and 10 m depth (Fig. 1). Grain temperature was also measured at the same locations at 0.5 m intervals down to 10 m depth. Surface populations were sampled using five pitfall probe traps ('STORGARD® WB Probe II', ex. Trécé Inc.)

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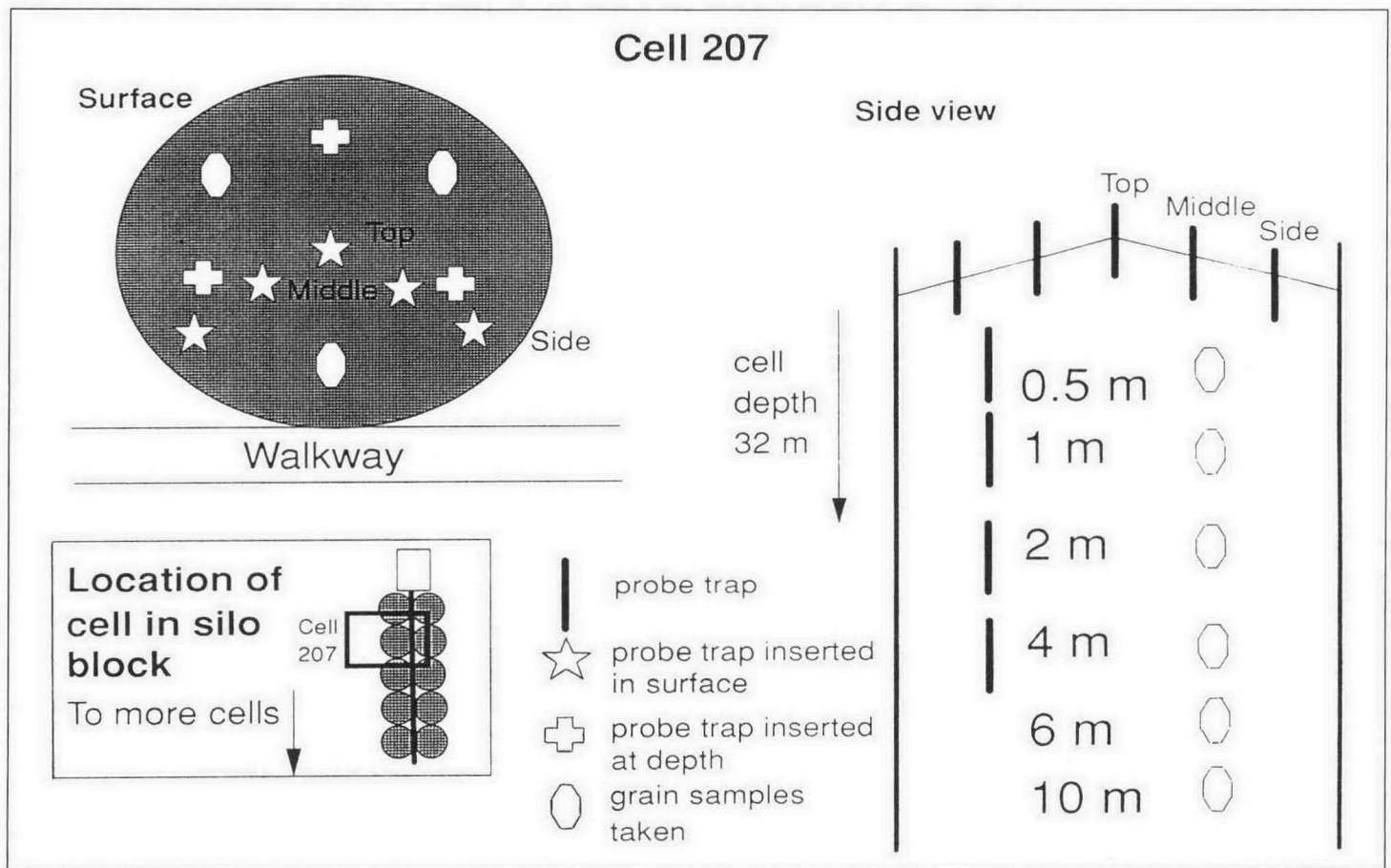


Fig. 1. Locations where pitfall probe traps were placed and grain samples taken.

partly buried into the surface of the grain: one at the peak, two half way up the peak and two near the cell wall (Fig. 1).

The contents of the cell were run out and transferred into four, 500 t capacity innerspace cells in the same silo block (Fig. 2). Grain was allowed to run out of the bottom of the cell at about 450 t/hour onto a conveyor belt. It was then lifted by bucket elevator and dropped onto the top conveyor belt before being tipped into another cell (Fig. 2). Grain samples (ca. 350 g) were taken at 10 minute intervals during grain movement at each of three locations. These locations (Fig. 2) were:

1. bottom of the cell, where the grain hit the conveyor belt;
2. from the top conveyor belt; and
3. from each innerspace cell as it was being filled.

From the conveyor belts (locations 1 and 2) samples were taken using a 500 mL capacity tin lowered by hand into the grain stream until it filled. Samples from the innerspace cells (location 3) were taken with a similar tin lowered on a rope from the cell hatch above and swung into the grain stream. Insects were extracted using a 2 mm gauge test sieve, and the number and identity of live specimens present was recorded. The moisture content of samples taken at the bottom of the cell (location 1) was measured using a Kett Riceter moisture meter calibrated for barley.

Once grain movement had finished, pitfall probe traps (one at each depth per innerspace cell) were inserted into the grain through the inspection hatch at 0.5, 1, 2 and 4 m depth. Traps were placed in the first three innerspace cells filled but not in the fourth as the grain surface there was inaccessible. After approximately 24 hours, traps were removed and their contents examined.

Results

Physical condition of grain

At the time of the investigation, mean (\pm SD) grain temperature of the top 10 m of grain was $20.1^\circ\text{C} \pm 1.14$. Temperature of the air above the grain was 17°C . Grain temperature had been reduced, by aeration, from about 30°C at harvest. Mean moisture content (\pm SD) was $11.7\% \pm 0.75$. The grain used in this study had been graded as 'weather damaged' as a result of having been wetted and dried several times before harvest.

Distribution of insects in grain before movement

Samples taken at depth (Table 1) showed that both *Liposcelis* spp. and *Cryptolestes ferrugineus* were distributed through the top 10 m of the grain bulk. On the surface *Liposcelis* tended to congregate on the grain peak (Table 2), where they appeared as a reddish-brown dusting. Large numbers were also seen climbing out of the cell onto walls and railings. A similar congregation was present in the ductwork leading to the conveyor cell. Many had passed through the cell valve and fallen onto the belt below. Almost all psocids collected in and out of the grain appeared to be adults. Probe traps buried in the grain captured beetles and psocids at all depths. *C. ferrugineus*, in particular, was caught in largest numbers in the top 1 m of grain (Table 3).

Psocids were extracted from every sample taken at location 1 (Fig. 3). The largest numbers were found in the first sample taken, which was grain from the metal ductwork leading from the cell bottom to the lower conveyor belt. *C. ferrugineus* was

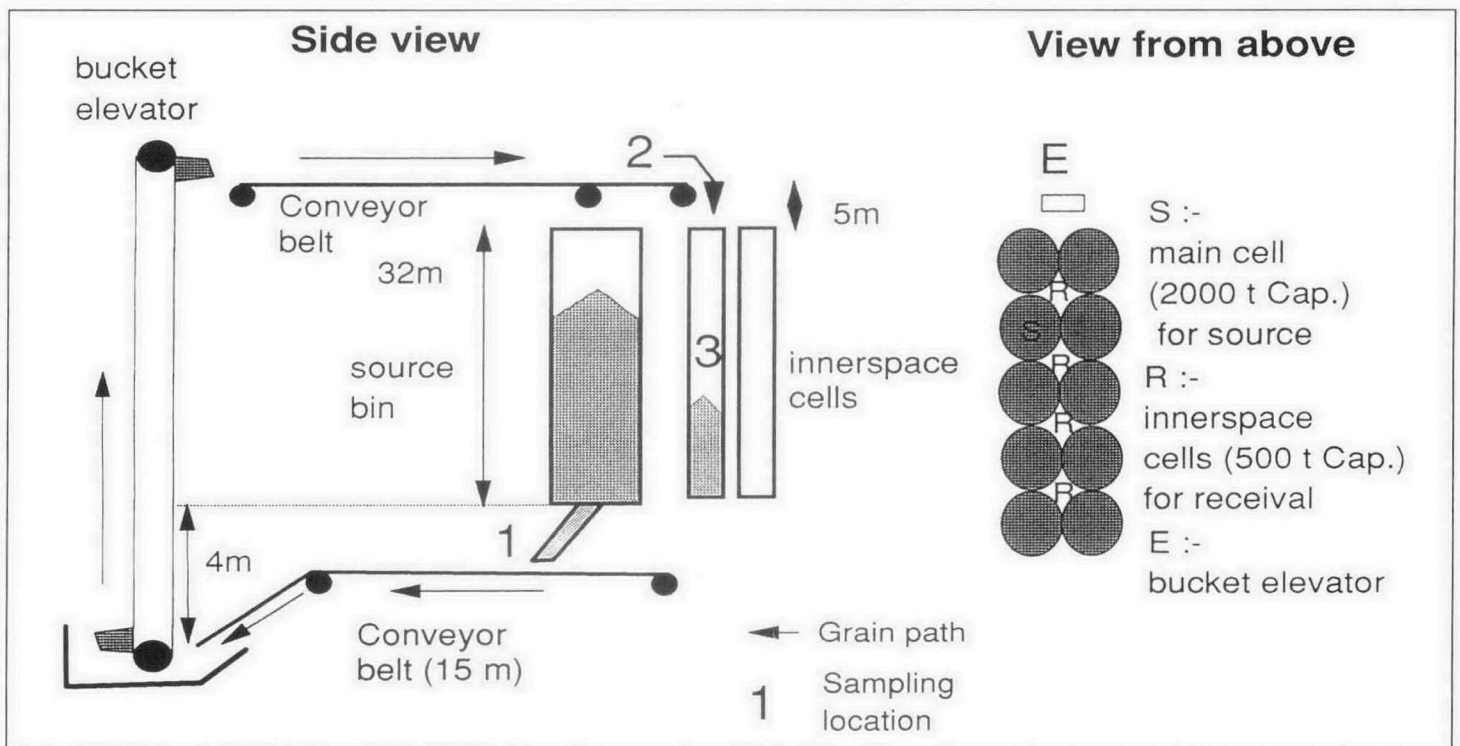


Fig. 2. Path taken by grain during movement.

Table 1. Number of insects (per kg^a) in samples of barley taken with probe sampler

Depth (m)	<i>Liposcelis</i> spp.	<i>Cryptolestes ferrugineus</i>
0.5	17	0
1	8	8
2	0	0
4	33	8
6	17	0
10	58	8

^aSample size 120 g, data adjusted to number per kg

Table 2. Numbers of *Liposcelis* spp. captured in pitfall probe traps left for 24 hours at the grain surface.

Location	Catch
Side	109, 540
Middle	1600, 100
Top	9800

present in smaller numbers than the psocids and mostly in samples taken at the beginning and towards the end of the emptying process (Fig. 3).

If a healthy adult *Liposcelis* weighs about 78 µg (Knülle and Spadafora 1969), compared with an adult *Cryptolestes* at 300 – 350 µg (D. Rees, unpublished data) the 156.12 million *Liposcelis* and 13.7 million *Cryptolestes* present in the cell of grain at the time of moving (Table 4) would weigh, respectively, about 12.2 and 4.1 kg.

Impact of grain movement on insect population

Large numbers of both *Liposcelis* and *Cryptolestes* survived the grain moving process (Table 4, Figs 4 and 5). A greater

Table 3. Mean catches ± SD^a from buried pitfall probe traps placed in grain before and after movement.

Depth (m)	Mean ± SD before	Mean ± SD after
<i>Liposcelis</i> spp.		
0.5	111.9 ± 120.8	92.7 ± 63.4
1.0	259.7 ± 36.5	358.0 ± 483.2
2.0	243.3 ± 63.0	83.3 ± 27.5
4.0	78.7 ± 105.2	43.0 ± 27.1
<i>Cryptolestes ferrugineus</i>		
0.5	43.0 ± 22.0	1.7 ± 2.1
1.0	32.0 ± 32.4	5.7 ± 6.4
2.0	8.0 ± 4.6	3.3 ± 1.5
4.0	3.7 ± 4.6	4.3 ± 6.7

^aTraps left in place for about 24 hours, mean of 3 traps per depth.

proportion of the *Liposcelis* appeared to have survived than *Cryptolestes*. A higher percentage weight of material was sieved from samples taken from the innerspace cells than from those of the conveyor belts. This is likely the result of the different sampling methods used. On the conveyor belts, immediately the sampling tins were filled they were withdrawn from the grain. This was not possible when taking samples from the innerspace cells as grain continued to rain down on the full tin as it was being pulled up and out through the inspection hatch. Grain fragments, dust, insects etc. could have continued to accumulate in the tin by being caught and pushed into the spaces between grains already in the tin. In order to make a comparison between samples taken at different sites, the numbers of insects are shown adjusted to the mean percentage weight of sievings in samples taken at location 1 from the bottom belt (Table 4, Figs 4 and 5).

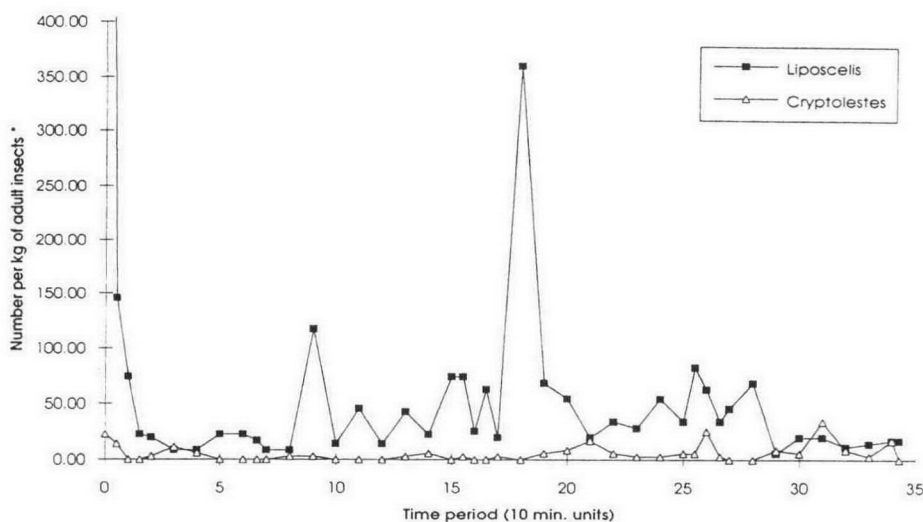


Fig. 3. Number of insects per kilo in grain samples collected at outlet of cell 207* on emptying. * Location 1 on Figure 2, at time period 0, number of *Liposcelis* spp./kg of grain was 1211.

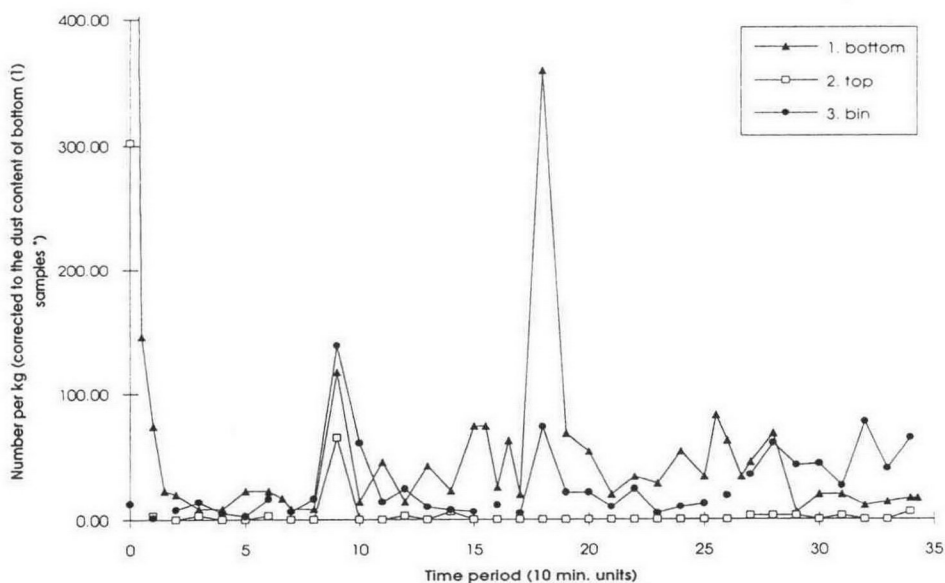


Fig. 4. Number of live *Liposcelis* spp. in samples taken during grain movement. * at point 1 (bottom), time period 0, number of *Liposcelis* spp./kg of grain was 1211

Table 4. Estimated numbers, in millions^a, of live adult insects in 2000 t of barley before and after movement.

Location	<i>Liposcelis</i> spp.		<i>Cryptolestes</i>		Mean % sievings in samples
	Unadjusted	Adjusted ^b	Unadjusted	Adjusted ^b	
1 Bottom belt	156.12	156.12	13.70	13.70	0.36
2 Top belt	24.36	26.12	9.89	10.79	0.33
3 Innerspace cell	126.92	56.04	4.94	2.18	0.81

^a Calculated from numbers of live adult insects in a sample multiplied by estimated quantity of grain that passed (grain flow 450 t / hour) until the next sample was taken. Number shown here is cumulative total.

^b Data were adjusted to show results based on a constant % of sievings (that of samples from the bottom belt). For number of insects at location 3 the following adjustment was made :Adjusted number at location 2 or 3 = Estimated total number at location 2 or 3 × (mean % sievings at location 1/% sievings at location 2 or 3).

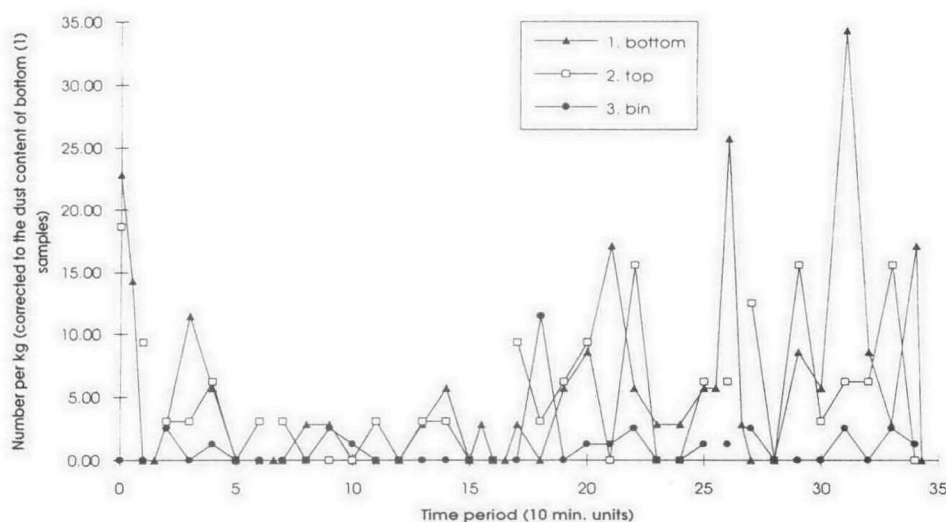


Fig. 5. Number of live adult *Cryptolestes ferrugineus* in samples taken during grain movement.

Peaks in the numbers of *Liposcelis* were noted in samples taken at time periods 9 and 18 and possibly 26. At these times, grain movement had been restarted following a break of between 20 and 60 minutes to permit machinery etc. to be moved and reset in order to fill the next innerspace cell.

Numbers of *Liposcelis* and *Cryptolestes* caught in pitfall probe traps after grain movement were mostly lower than those captured beforehand (Table 3). However, these traps confirmed that many insects remained alive in the grain after the movement.

Discussion

Liposcelis spp. clearly survived grain movement at least as well as, if not better than, did *Cryptolestes ferrugineus*. Such movement of grain could therefore not be relied upon to give satisfactory control of these species. Depending on conditions of temperature and humidity, insects remaining could very rapidly recover in numbers, be it in another silo cell or on board a ship. One of the two *Liposcelis* species present, *L. bostrychophila*, is known to be parthenogenic so that a single individual, egg, nymph or adult, may initiate an infestation.

A widely held perception amongst workers at grain handling facilities is that psocid infestations are confined to the grain surface. While *Liposcelis* were seen swarming on the surface and at the cell outlet, it was clear from this study that they were distributed throughout the entire grain bulk. Given their ability to move quickly and their very flattened form, they appear physically able to move freely through any bulk of grain. Many individuals appear to 'fall through' the grain and collect in the bottom of the cell. This process appears to occur rapidly and may explain the peaks in psocid samples taken after breaks in movement of grain. In many silos, especially those with capped vertical cells, access to the grain surface is often difficult, but the bottom of the cell where it leads to a conveyor belt is usually accessible and seems to be a good place to detect a serious infestation of *Liposcelis*.

The grain used in these studies was, as a result of aeration, relatively cool (ca. 20°C). At these temperatures, *Liposcelis* spp. breeds slowly (Spieksma and Smits 1975; Rees and Walker 1990). However, adult longevity is known to increase with reduction in temperature, subject to a lower limit, around 0°C for *L. bostrychophila* (Turner and Maude-Roxby 1988), at which the insect is likely to be killed by cold. For *L. bostrychophila*, maximum adult longevity, without food, increases from about 10 to 60 days when the temperature falls from 30 to 20°C (r.h. = 60%) (Turner and Maude-Roxby 1988). With food, longevity at any temperature is likely to be greater. The large numbers of individuals observed in this study are likely to have built up when the grain was warmer; at harvest, grain in this area of South Australia is often over 30°C. The rate of increase will have been reduced by reduction in grain temperature. This, coupled with extended adult longevity, would in time produce a population like that seen, consisting mostly of mature individuals.

Even for those individuals not in the grain bulk, ambient conditions during winter at such a coastal location are very unlikely to be fatal to *Liposcelis*, with humidities remaining high and temperatures rarely dropping below 10°C. Many individuals seen leaving the grain were likely to survive, living in the fabric of the building. In summer, however, very high temperatures and lower humidities may prevent them from ranging as widely as we observed and may restrict them to areas in which the microclimate remains favourable. In any large structure, such as a grain terminal, favourable locations, for example, cracks, crevices, service ducts etc. will invariably be present. In this and similar storage facilities located elsewhere in the temperate and Mediterranean regions of Australia, there is some anecdotal evidence to show that psocids are more noticeable in the autumn, winter and spring than during the summer.

Liposcelis appeared to form the largest component of the pest biomass in this particular batch of grain. What impact these psocids had on grain quality compared with the *Cryptolestes* present would have been difficult to determine.

However, the likelihood is that they had at least as great an impact. *Liposcelis* are not just mould feeders; they will also eat grain germ and damaged grains (Watt 1965; McFarlane 1982; Rees and Walker 1990). Given their liking for grain germ, the effect that such population levels of *Liposcelis* could have on commodities such as seed grains and malting barley needs to be urgently investigated.

The large number of *Liposcelis* captured in the pitfall probe traps suggest they could prove to be an effective monitoring tool to detect populations of these insects both at the surface and at depth. Pitfall probe traps may prove especially useful in horizontal sheds, trucks and rail wagons where the grain surface is usually accessible.

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