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The psocid *Liposcelis bostrychophilus* Badonnel (Psocoptera: Liposcelidae): an occasional herbarium pest

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ABSTRACT

The herbarium pest *Liposcelis bostrychophilus* is described and illustrated. Aspects of the insect's life cycle and eradication are discussed. Where possible, non-toxic methods, such as sterile-entry techniques of control, should be used. If infestations are epidemic and serious damage is being incurred, there may be no alternative but to use pesticides or fumigants.

UITTREKSEL

Die herbariumplaag *Liposcelis bostrychophilus* word beskryf en geïllustreer. Aspekte van die insek se lewensiklus en uitroeiing word bespreek. Waar moontlik, moet nie-toksiese metodes, soos steriele-ingangstegnieke vir beheer, gebruik word. Indien besmettings epidemies van aard is en ernstige skade sou berokken, is plaagdoders of berokingsmiddels waarskynlik onvermydelik.

INTRODUCTION

One of the most serious problems in herbarium curation, especially in tropical regions, is the protection of valuable plant specimens from damage by insects. In the past, various animal pests have been encountered at the National Herbarium in Pretoria (PRE), including cigarette beetles, cockroaches, rats and fishmoths. Of these, *Lasioderma serricorne* (F.), the cigarette or tobacco beetle, has caused the most severe damage to herbarium specimens (Retief & Nicholas 1988). The National Herbarium Pretoria is located on the southern African highveld, and conditions here are quite different from those encountered at one of its satellite herbaria, the Natal Herbarium (NH) in Durban. Unlike Pretoria, where conditions are usually moderate to cold and dry in winter, Durban has a more tropical climate, with warm and humid conditions. As a result, a psocid, rather than *L. serricorne* is the primary pest in this herbarium. In 1986, during one of these psocid infestations, samples of the insect involved were collected for study and identification. By obtaining a correct scientific name it was hoped that, through the literature, a greater understanding of the pest could be reached, including a suitable, safe method of eradication. The insect was identified as the common booklouse: *Liposcelis bostrychophilus* Badonnel (fide C. Lienhard of the Museum d'Histoire Naturelle, Genéve), of the Order Psocoptera (Figure 1).

It should be mentioned, however, that these insects are not true lice, which belong to the Order Mallophaga, and that the common names booklice or barklice are therefore misleading. Although common names are generally of little scientific value, the term psocid, given to members of the psocopteran family Psocidae, does seem more appropriate.

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DISCUSSION

Psocid taxonomy and general information

Liposcelis Motschulsky belongs to the family Liposcelidae in the suborder Troctomorpha. In this suborder parthenogenesis is frequent, and Pearman (1928) believes that in many species the male is not a vital necessity for reproduction; certainly this is true of *Liposcelis bostrychophilus* which is an obligated parthenogen; males have never been found. *Liposcelis* is characterized by being moderately dorsoventrally depressed and completely apterous (without wings) in both sexes. The coxae are ventrolaterally inserted and their articulation with the thorax is therefore not visible from above. The broad hind femur has a dorsal, obtuse protuberance at its widest point. The genus contains a number of species complexes with inherent taxonomic difficulties; one such complex includes *L. bostrychophilus* and *L. corrodens* Heymons (Broadhead 1950).

Members of the family Liposcelidae can be distinguished by their dorsoventrally depressed bodies, elongate-oval abdomen, hindlegs not extended beyond the apex of the abdomen and antennae not longer than ½ to ¾ the length of the body (Smithers 1985).

Most members of the family Liposcelidae are found in association with dry leaves or under bark, although some appear to be associated with grass galls or with ants' nests. A few psocids have become pests by inhabiting man-made structures (including homes) and damaging his resources (especially stored goods). Through commerce these particular species are now quite cosmopolitan in distribution.

although Broadhead (1950) points out that air currents may also help in the dispersal of these small insects, live specimens having been collected on air currents at altitudes of 150 m or more. These species are usually not harmful to man and are generally included in the category of nuisance, although they should be regarded as a warning that environmental conditions are becoming ripe for proliferation of other insect pests (Hickin 1985). Although not true ectoparasites, there are a few very rare reports of infestations of living animals (Gurney 1950), such as humans, dogs, chinchillas and possibly birds. However, psocids seem to occur on living animals only under exceptional, usually unhygienic circumstances.

Smithers (1967) lists 58 species of *Liposcelis*, although an anonymously annotated copy of this list housed at the Entomology Department of the Natural History Museum in London (seen in 1990) catalogues a further 44 names, constituting a genus of approximately 100 species, possibly more. The last detailed revision of the genus is that of Broadhead (1950), who listed only 24 species. According to Smithers (1985) 80 species of the Order Psocoptera (in some 34 genera) and 12 species (in three genera) of the family Liposcelidae have been recorded in southern Africa.

Psocid pests

Gurney (1950) reported that no more than a dozen psocids are known to be pests, but Mockford (1991) recorded some 50 species as occurring on stored foods. These pest species are usually soft-bodied, 1 to 2 mm long, wingless or with very short oval wings, with chewing mouthparts (Figure 2C, D) and a large, swollen postclypeus (the upper exoskeletal plate that covers the mandibles—Figure 2B); the antennae are thread-like with many segments, parthenogenesis is common, and the majority of species have six nymphal stages (although metamorphosis in the egg and nymphal stages is incomplete). They feed largely on microflora such as fungal molds but, being polyphagous, may also eat pollen and other organic materials, including dead animal (mainly insect) and plant remains (such as straw). In the food industry they have been reported as feeding on bananas, barley, biscuits, cereal products, chocolate, cocao fruits, cornflour, diary products, fish meal, flour, linseed oil-cake, maize, meat products, nuts, oil seed, potato products, semolina, sugar, wheat, and even salt (Downing 1985; Pearman 1929, 1942). They are also often associated with packing materials (Society of Food Hygiene Technology, hereafter abbreviated as SFHT 1983), a factor which may have contributed to the widespread distribution of domestic species. Psocids tend to thrive and swarm in unused rooms where humidity and temperature are high and lighting poor. Populations have been reported to increase in heated buildings (Mockford 1991), and Spieksma & Smit (1975) have shown that *L. bostrychophilus* remains are a common component of dust in centrally heated homes.

Besides causing damage by feeding, they are a nuisance if present in large numbers and may contaminate, directly or indirectly, foodstuff with which they come into contact. In 1981 the SFHT held a symposium at which the problems created by psocids for the food industry were discussed (Downing 1985). The three most important psocid pests reported by the SFHT (1983) are *Trogium pulsatorium*, *Lepinotus patruelis* and *Liposcelis bostrychophilus*. However, whereas *Trogium* and *Lepinotus* tend to be associated with manufacturing premises and pallets, *Liposcelis* is usually the source of consumer complaints (Downing 1985). All three are of widespread occurrence in houses. *Liposcelis bostrychophilus* (which is brownish in colour) and *Trogium pulsatorium* (large, pale and whitish in colour) are both important pests in museums (Edward *et al.* 1980), and Broadhead (1950) report *Liposcelis entomophilus* (Enderlein), *L. liparus* Broadhead, *L. kidderi* (Hagen) and *L. terricolis* Badonnel as infesting both insect collections and herbaria. As demonstrated by the infestation at the Natal Herbarium in 1986, *L. bostrychophilus* can be added to Broadhead's list.

It should also be noted that most psocids are not pests. In fact, most of them play a vital role by making micro-organic debris and microflora available to the lower rungs of the food chain (Smithers 1985). Even psocids associated with human habitations may play a useful role in checking fungal growth in dark, damp places (Pearman 1928).

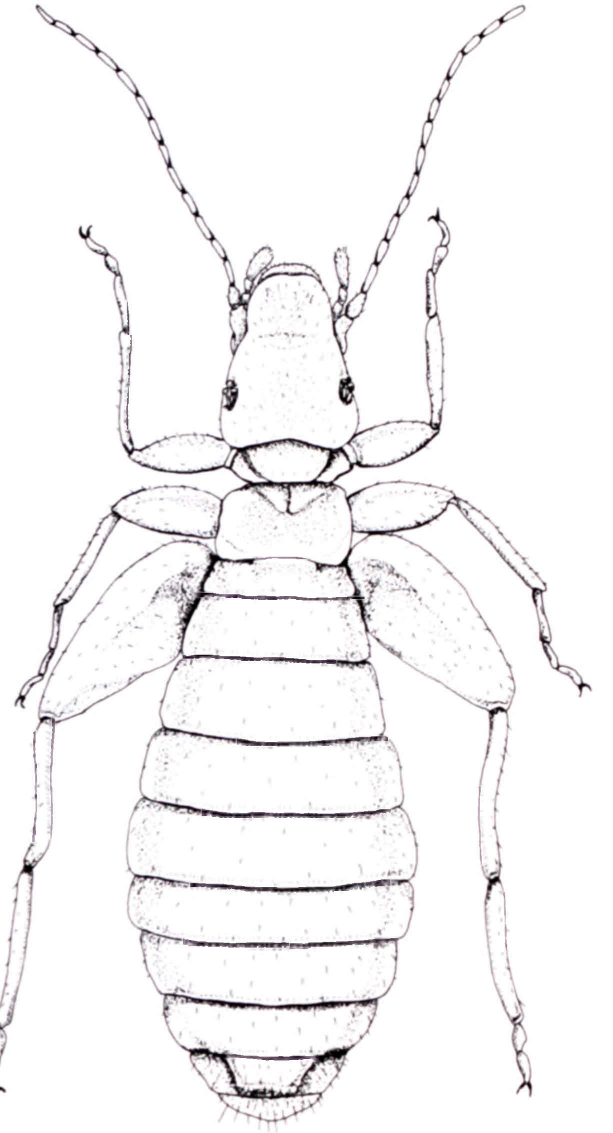

FIGURE 1.—*Liposcelis bostrychophilus*. Dorsal view, × 113. Illustration by Heather Borchers.

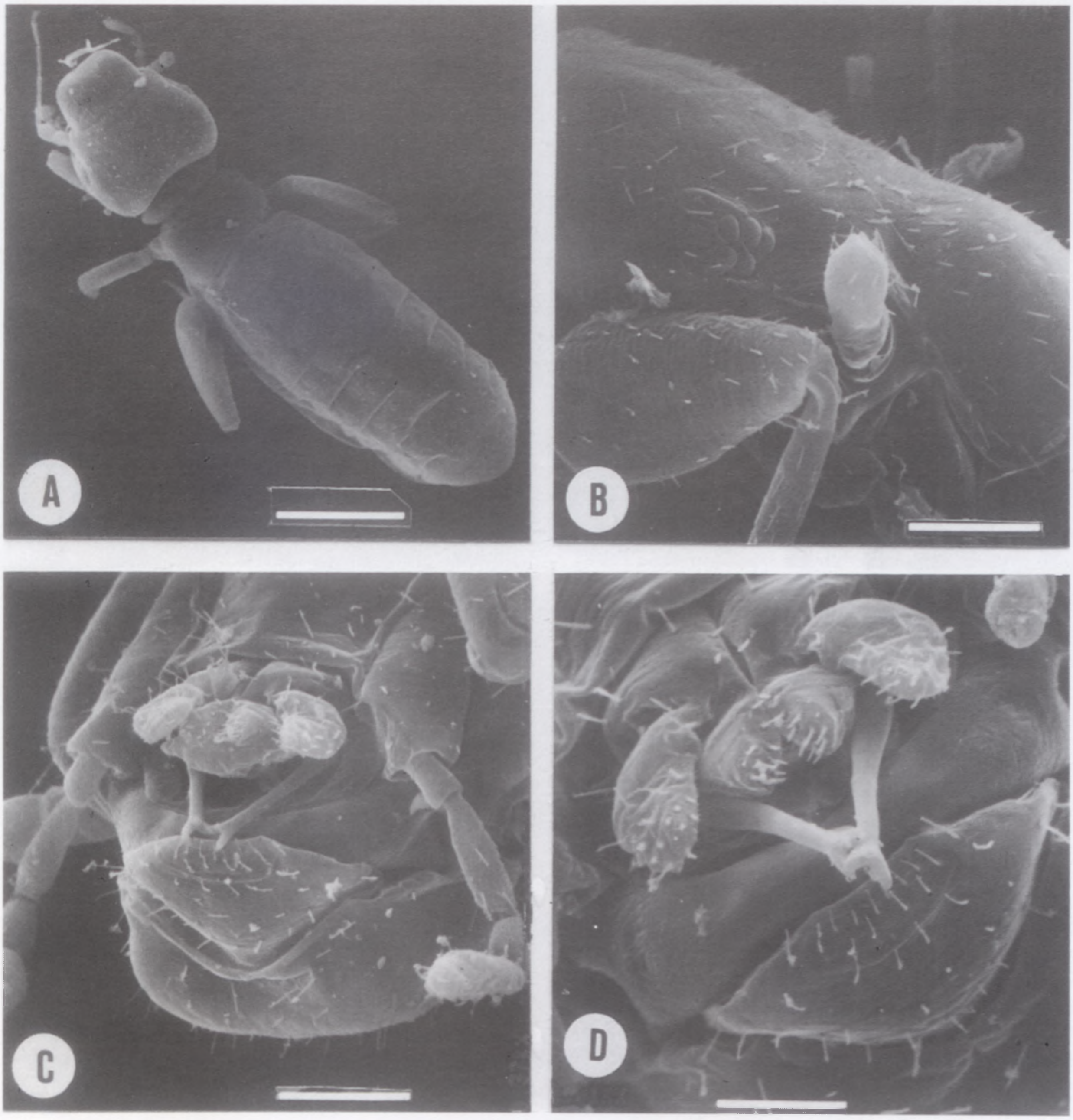

FIGURE 2.—SEM micrographs of *Liposcelis bostrychophilus*. A, dorsal view of whole insect, × 4.6; B, side view of whole head, note small group of seven ommatidia and swollen postclypeus, × 202; C, mouthparts, × 213; D, close up of mouthparts, note strong, rod-like laciniae, × 352.

Liposcelis bostrychophilus Badonnel

Liposcelis bostrychophilus was described by Badonnel in 1931. However, it has also been widely recorded as *L. divinatorius* (Müller) non Pearman, *L. divergens* Badonnel, and *L. granicola* Broadhead & Hobby (the latter two now regarded as synonyms of *L. bostrychophilus*). Broadhead (1950) presumed that the species probably originated in Africa and was later introduced into Europe; today it is cosmopolitan. It forms a species complex with *L. corrodens* and non-specialists may find these species difficult to tell apart.

Description

Liposcelis bostrychophilus is a minute insect, 1.0–1.5 (–2.0) mm long. It has a soft, semi-transparent, dull brown body sparsely covered with short hairs (Figures 1, 2). The head is large and mobile and the neck is relatively narrow (Figure 2A). The compound eyes are reduced to groups of seven small ommatidia restricted to the side of the head (Figure 2B). The mouthparts comprise a pair of strong rod-like organs, the laciniae, which are furnished with three teeth at the end (Figure 2C, D). The antennae are long and thread-like. Wings are absent but the insect is capable of surprisingly rapid movement for its small size. The legs are short with a thickened hind femur which has a blunt tooth-like projection on the front margin (Broadhead 1950; Gurney 1950; Von Kéler 1953; Spieksma & Smit 1975; SFHT 1983; Mockford 1991).

Life cycle

On average about 100 sticky eggs, each more or less one third of the length of the female, are laid over a ±

five month period. One female was recorded to have laid as many as 122 eggs during her life span (Spieksma & Smit 1975). The eggs, usually laid singly in cracks or on dusty surfaces, are smooth and bluish white or pearly coloured, but become dull as development proceeds. Under ideal conditions they take 10 days to hatch. The nymphs hatch from the egg by means of a saw-like egg-buster (Hickin 1985). These nymphs resemble the adult stage except that they are more fragile in appearance, paler in colour, and various body segment parts may vary in number with each instar. There are four nymphal instars, lasting 12–15 days in total, before the adult stage is reached. Within 2 to 3 days of reaching maturity, females start producing eggs. Adults may live for 150–175 days, sometimes less, and egg-laying takes place irregularly. There may be two to eight generations per year, depending on environmental conditions and food availability. No males are produced, reproduction taking place without the need for fertilization, i.e. by parthenogenesis. Under unfavourable conditions development is slower and the life cycle takes longer (Broadhead 1950; Gurney 1950; Spieksma & Smit 1975; SFHT 1983; Hickin 1985).

Factors affecting the life cycle

Temperatures of 25°C and a relative humidity of 75% present ideal conditions for *L. bostrychophilus*. The species is affected detrimentally by lower temperatures and humidity, but specimens have been known to survive short periods of freezing (Downing 1985). In cold buildings the insect may overwinter in the egg stage, but under warmer conditions such hibernation does not occur. Spieksma & Smit (1975) have shown that populations increase with increasing temperature and humidity. Their results show that (at the ideal humidity level) populations increase by 500% at a temperature of 21°C and by as much as 2000% at 27°C. Spieksma & Smit (1975) found no population increase at humidities below 40–50%, only slow growth at 50–60%, and rapid increases at 70–80%. Above 80% humidity, moulds become abundant on food sources and help to increase the populations of the insect even more dramatically. The results of Spieksma & Smit (1975) apparently match those of Knülle & Spadafora (1969) who found the critical equilibrium humidity for *L. bostrychophilus* to be 60% relative humidity at 25°C. Critical equilibrium humidity is that level of humidity where it is possible for the insect to absorb moisture directly from the surrounding air; below this critical level the insect will tend to loose moisture and eventually die. Thus, under the right conditions of temperature and humidity, populations can experience an exponential growth. Such population explosions are no doubt helped by the fact that this species has a totally parthenogenic life cycle (Downing 1985).

L. bostrychophilus is negatively phototactic, moving away from the light into the dark. However, Spieksma & Smit (1975) have shown that the inhibiting effects of exposure to light on laboratory populations are minimal. Although this may be true under ideal conditions, it is unknown whether light may have a greater impact on population growth if environmental conditions are unfavourable and food resources limited. Spieksma & Smit (1975) have also shown that yeasts, if present with other food sources, accelerate population growth.

Damage

Although feeding primarily on microscopic flora, particularly fungi (including naturally occurring yeasts), these insects may also eat and damage other organic matter, including organically produced glues and pastes used for binding books or mounting specimens. They also tend to damage paper that has become damp and mouldy. Of more importance to curators, herbarium specimens themselves (not just their mounting boards) may be attacked, causing a fine powder to be scattered around the eaten and therefore damaged plant organ. Such damage may be inflicted on a wide range of dried plant specimens, but is usually confined to delicate flowers, such as those of *Wahlenbergia* (Figure 3A, B), although on rare occasions,

FIGURE 3.—A, B, herbarium specimens of *Wahlenbergia* spp. showing *Liposcelis bostrychophilus* damage. Note the debris (mostly faecal) surrounding partially eaten flowers.

woody structures may also be damaged, such as *Maytenus* stems. Unfortunately, psocids are usually only spotted when populations are high and damage already advanced. When infected herbarium boards are exposed to bright light they display a mass of tiny, pale brown bodies frantically dashing for shelter. If squashed, these insects will stain paper, including herbarium sheets. This staining of paper is particularly distressing to curators of valuable archival material, especially books and old manuscripts.

Control and eradication

If possible, non-toxic methods of control and eradication should be used; however, if infestations are epidemic and serious damage is being incurred, there may be no alternative but to use pesticides or fumigants. After collection in the field, plant specimens should be dried as quickly as possible to prevent the growth of fungal mycelia or yeasts on and within the specimen; the presence of these microfungi will only encourage psocid infestations. Sterile-entry techniques should be practiced, with herbarium collections being sealed off from the outside environment as much as possible. This must include non-herbarium rooms or offices near or adjacent to the herbarium itself. Before being transferred directly to the sealed building housing the collections, specimens should be frozen at temperatures below −8°C for 48 hours in a building separated spatially from the herbarium (Forman & Bridson 1989). Other physical methods of pest control (such as heating in a microwave oven) may also be practised as part of a sterile-entry procedure (Stansfield 1989).

However, all these physical methods affect plant specimens in undesirable ways (some albeit more than others) and so decrease their scientific value. An alternative to physical sterilization is chemical sterilization. Suitable chemicals are, however, all poisonous and care has to be taken when using them. Forman & Bridson (1989) list and discuss some of the more common treatments presently used by herbaria. Unfortunately, these chemical methods may also damage plant specimens. Herbaria should therefore decide how their collections are to be used before selecting a suitable physical or chemical sterilization technique (some herbaria combine elements of both). For instance, herbaria in which the removal and growth of spores or seeds is important, should definitely not heat or treat specimens in microwave ovens, even though this technique does not affect gross pollen structure (Arens & Traverse 1989). Freezing seems to be the best of the physical methods of sterilization, although this technique may affect seed and spore viability and may also turn incompletely dried succulent plants black and mushy. Poisons mixed with alcohol or other tetracarbons (mercuric chloride if mixed in alcohol and lauryl pentachlorophenate [LPCP] if mixed with white spirit) may damage plant microstructures, particularly if these contain lipids. Such microstructures are often important taxonomic characters and need to be preserved intact. There is also a chance that very toxic and deeply penetrating poisons (such as mercuric chloride mixed in alcohol) may kill spores and seeds. Unfortunately, it is usually these types of poisons that are most effective for preventing insect attack.

The extraction of DNA samples from herbarium specimens (especially extinct species) may soon become routine and it is not yet known how present sterilization treatments may affect this important plant component. In particular, exposure to gamma radiation (used by a few institutions) may affect the DNA structure of some pressed plants. Unfortunately, because pests are such a problem in the tropics, herbaria situated here often have little choice but to take what they see to be the lesser of a number of evils. However, such herbaria should be encouraged to send pristine (i.e. physically undamaged) duplicates to temperate herbaria where they may be useful to systematic and conservation researchers.

The one major weak link in the life cycle of *L. bostrychophilus* is its intolerance to low humidity. If the humidity of a building can be maintained below 50%, infestations of this pest should not occur. This may necessitate the installation of air-conditioning in herbaria that suffer repeated plagues of this insect. Herbaria unable to install air-conditioning, or in which the air-conditioning is proving ineffective in maintaining the humidity below 50%, may try putting a desiccant, such as silica gel, inside the herbarium cupboards. Silica gel removes moisture from the air and, being non-toxic, is people-friendly. Unfortunately, silica gel needs to be replaced or dried every three months (shorter intervals may be needed in very humid localities) if it is to remain effective. This procedure is therefore labour-intensive and costly. Another advantage of keeping the humidity low is that it helps to eradicate other insect pests, including the more commonly encountered cigarette beetle.

Some publications advocate humidity control in conjunction with fumigants or insecticides (Downing 1985; SFHT 1983), and such combination treatments may be needed in tropical situations where infestations can cause irreparable, costly damage if not checked. However, herbarium curators should be aware that poisons, by their very nature, are potentially harmful to man; some may cause allergies, illness and even death if not administrated properly. If in doubt, experts should be hired to apply or administer fumigants and pesticides that are extremely toxic (see Bot *et al.* 1987; Stommel 1991). Localized infestations can be controlled or exterminated using commercially available dry sprays that do not mark or damage herbarium specimens (Retief & Nicholas 1988).

Resin blocks impregnated with dichlorvos have also been used to eradicate infestations, the insecticide being slowly released into the atmosphere over a three month period. Most of the arguments against the use of dichlorvos are based on anecdotal accounts (Bartle 1991) which tend to appear in the popular rather than scientific press (Sapa-Reuter Washington 1988). The substance was used in a wide range of household insect sprays in southern Africa (Central Standardization Committee 1978). Dichlorvos is an organophosphate that inhibits the functioning of nerve-related enzymes. It is therefore a poison and should be handled sparingly and with caution. Fumigants or foggers containing dichlorvos are a fairly effective and cheap way to eradicate or control infestations; this makes them attractive to herbaria with limited finances, which are unable to afford more costly treatments. In some countries dichlorvos foggers are readily available and may be purchased in supermarkets. The poisonous ingredients take 48 hours to break down and herbarium staff should not be allowed into fumigated rooms during this period, also the effects of overexposure to high concentrations can be extremely serious (De la Viña *et al.* 1990; Anonymous 1991; Bartle 1991).

A double dichlorvos fogger fumigation technique (timed in such a way as to eradicate all stages of the life cycle of the cigarette beetle) was used with some success at the National Herbarium Pretoria in 1988. The technique was not costly and, wearing specially designed protective masks, the staff were able to administer the treatment themselves. It cannot be emphasized strongly enough that curators who are unsure of how to administer or apply poisons of any kind should seek expert help. They should also be aware of the risks involved and communicate these to staff that may come into contact with poisonous substances under working circumstances. Curators concerned with the welfare of their herbarium staff should see that they continually receive in-house or out-house education on all matters concerning herbarium hygiene; especially where health issues are concerned.

Insect pheromones are probably non-toxic to humans and are being used more and more as part of an effective insect pest control programme in some institutions (Anonymous 1989; Biological Control Systems pamphlet ± 1990a, b). Experiments using a pheromone for the cigarette beetle, *Lasioderma serricorne*, were initiated at the National Herbarium Pretoria in 1990. These sex-attractants (if used in connection with specially designed traps) may be effective in reducing insect populations but not in eradicating them. It must be remembered that these chemicals affect neither the females of the population nor sexually inactive or immature males. The fact that they do not eradicate pest populations is their biggest drawback as effective weapons against infestations; even a minimal pest population can continue to cause damage and the potential for disaster remains ever present. The major role the pheromone traps can play in pest control in herbaria is to act as an infestation warning device and for monitoring the course of such infestation. Usually, infestations are only noticed by herbarium workers when the numbers of the pest are already high and damage therefore quite substantial. Pheromone traps can help detect infestations before they reach this point and so alert herbarium staff to the problem at a time when damage can be minimized and pest populations isolated and destroyed. An insect-produced chemical holding greater promise than pheromones appears to be ecdycin. Apparently this chemical disrupts moulting, an essential process in the insect life cycle.

Although *Liposcelis bostrychophilus* may not cause as much damage to herbarium specimens as the cigarette beetle, the presence of this psocid should be seen as a warning that conditions are ripe for infestation by other, more destructive insect pests (Hickin 1985). This being the case, their presence should be viewed by curators with some concern.

CONCLUSION

The control of herbarium pests is of primary concern to all herbarium curators, especially in tropical regions of the world where ideal conditions for pest infestations occur. Hot, humid areas, such as those found along many tropical and semitropical coastlines, are ideal for the growth of the psocid *Liposcelis bostrychophilus*. Under ideal conditions in tropical herbaria, populations of these wingless, parthenogenic insect pests can build up very rapidly and so cause damage to books, specimens and herbarium packaging. Sterile-entry techniques, coupled with a controlled humidity lower than 50%, will generally eradicate or prevent infestations by these particular insects and should, therefore, be tried in preference to application of toxins. However, persistent infestations or those reaching epidemic proportions may call for sterile-entry and/or low humidity conditions, coupled with a fumigation or with the application of pesticides, if irreparable damage is to be prevented.

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