

The Resurgence of Bed Bugs in Australia: With Notes on Their Ecology and Control

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During the first three years of the 21st century, bed bug numbers in Australia have undergone a dramatic rise. The Department of Medical Entomology, Institute of Clinical Pathology and Medical Research (ICPMR), Westmead Hospital, Sydney, has recorded an increase of over 400% in the number of bed bug samples submitted to its pathology service, since the beginning of 2001. Over the last four years, the pest control industry has noted a major resurgence in the number of bed bug treatments, with one company reporting an increase of almost 700%. The Australian Quarantine and Inspection Service has also recorded a similar trend, with a large increase in interceptions over recent years, and the majority of interceptions have been from the luggage of travellers. The resurgence of bed bugs is part of a worldwide trend, although the reasons for the increase have not been scientifically resolved. Many factors are probably contributing to the upsurge, with increasing world travel being suggested as the main cause as the insects are transferred through the movements of travellers. The trade in second-hand furniture, changes in pest management practices, the lack of awareness of bed bugs among pest controllers and health professionals, and other phenomena may all have contributed to the spread and increase in bed bug numbers. A review of this public health pest is provided.

Key words: Bed bugs; Resurgence; Cimex; Interceptions; Australia

Bed bugs are blood-sucking insects belonging to the family Cimicidae (Order: Hemiptera). Of the 89 species within the family, there are two that mainly bite humans, the common bed bug, *Cimex lectularius* Linnaeus, and the tropical bed bug, *Cimex hemipterus* Fabricius. Bed bugs were once a common public health pest worldwide, with estimates of up to 75% of homes in Britain infested (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). In developed nations, they declined in incidence and, through improvements in sanitation and with increasing use of residual insecticides, infestations became a rare event. However, this downward trend is now starting to reverse and globally there have been recent reports of an increase in

bed bug numbers (Boase 2001; Krueger 2000; Paul & Bates 2000). Some areas in Britain (*Professional Pest Controller*, 2003, vol. 32, pp.16-7) and the United States (Baumann 2002; Krueger 2000) have reported a tenfold increase since 1999. Australia has not been excluded and a dramatic rise has also been observed here. Unfortunately, evidence for the trend locally is anecdotal, as data on bed bug incidence are not collected systematically. Compounding this is the dearth of scientific reports relating to bed bugs in Australia, which means that there has been a notable lack of accurate and up-to-date information available to health professionals and pest managers. This article provides documented evidence for the recent rise in bed bug

numbers and attempts, for the first time anywhere in the world, to examine how they may have been introduced. Finally, as public health and environmental health workers will be called upon to provide advice on the management of bed bugs, and as there is limited information in Australia, a brief review of bed bugs is provided with notes on their identification, clinical significance, ecology and control.

Methods

Evidence was sought to substantiate the anecdotal reports of the increase in bed bug infestations. The number of specimens submitted to the pathology service of the Department of Medical Entomology was tallied over time and information on when each was submitted, along with the species identity, was recorded. Three large local pest control firms were contacted and information on the number of bed bug treatments and the type of premises treated was requested. Health workers across the country were also contacted regarding the apparent increase. To determine how the bed bugs may have been introduced, a list of the interceptions by the Australian Quarantine and Inspection Service (AQIS) was requested from the Pest and Disease Information Database (PDID), Market Access and Biosecurity, Department of Agriculture, Fisheries and Forestry, and the AQIS Incidents database, covering the period 1 January 1986 to 31 January 2004. This also provided a time line of the interceptions, which could contribute evidence for the alleged upward trend in bed bug infestations.

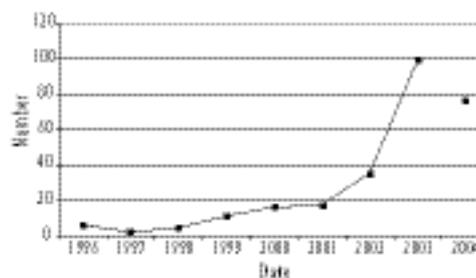
Results

The Department of Medical Entomology, ICPMR, is the only NATA accredited pathology service in Australia for the identification of arthropods of medical importance and, as such, is possibly the main government health body receiving arthropod specimens of medical and public health importance. From the beginning of

January 2001 to May 2004, the Department received 37 samples of bed bugs, representing an increase of over 400% upon the four-year period of 1997 to 2000 (nine samples submitted). A total of only 16 bed bug samples was received through the years 1988 to the end of 2000. Around 80% of the bed bugs were submitted during summer and autumn, and all were from within Australia. The common bed bug was the most frequent species (46/53), while all ten records of the tropical bed bug came from Queensland. Three of the samples contained both species.

One pest control company (Jones, G. Eagle Pest Control, 2004, *pers. comm.*) has recently observed almost an exponential increase in the number of treatments; a rise of approximately 700% for 2001-2004 (figures up to the end of April), compared with the four years 1997-2000 (Figure 1). One highly experienced pest controller estimated that he had been involved in some 50 treatments of bed bugs from late 2000 compared with some five in the preceding 25 years (Lamond, P. Field Biologist, Pest Control Division, Rentokil Initial, 2004 *pers. comm.*). The majority of treatments have been in budget style accommodation and backpacker hostels, which have high visitation from overseas guests (Jones, G. Eagle Pest Control, 2004, *pers. comm.*). However, recent sites have included private homes, 'up-market' hotels, interstate trains, charter boats, and even ocean going cruise ships.

Figure 1: Number of bed bug treatments undertaken annually by Eagle Pest Control, 1996 to 2003, and for 2004 up to and including April only.



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Other agencies also have observed the increase; the South Eastern Sydney Public Health Unit, NSW Health, started receiving a dramatic increase in complaints about bed bugs in November 2002 and has investigated 15 such infestations since that time. The majority of these were in shared accommodation in the beachside suburbs of eastern Sydney (Cains, T. Environmental Health Officer, South Eastern Sydney Public Health Unit, 2004, *pers. comm.*). The Pesticide Safety Branch, Western Australia Department of Health, has noticed a marked increase in bed bug enquiries over the last six months (Gregory, K. Scientific Officer, 2004, *pers. comm.*). No other state health department contacted by us has documented an increase.

AQIS reported some 23 interceptions of bed bugs since 1986 when the database was established (Table 1). Some 74% (17/23) of the detections has occurred since 1999 and at least 74% (17/23) has come through personal baggage, with most (15/23) via air travel. The country of origin of the bed bug importations is difficult to determine as the database records the 'last port of call', namely the last country visited. Despite this, the majority where known (13/19) recorded the Asia/Pacific region as being the last port of call. The bed bugs were detected in a variety of goods, with woven materials being most frequent (5 of the 22 known). The common bed bug, when identity was known, was the most frequently detected species (13/17).

Table 1: Bed bug interceptions by the Australian Quarantine and Inspection Service, from 1 January 1986 to 31 January 2004¹

Interception Date	Country of Origin ²	Method of Import	Goods	Species ³
23-Nov-90	Fiji	Sea baggage	Dried curry powder	<i>Cimex lectularius</i>
16-Oct-92	Unknown	Post	Packing Boxes	<i>Cimex lectularius</i>
21-Dec-96	Papua New Guinea	Air baggage	Carvings	<i>Cimex lectularius</i>
22-Jul-97	Kenya	Air cargo	Fresh Roses	<i>Cimex lectularius</i>
06-Feb-98	India	Air cargo	Fresh Roses	<i>Cimex lectularius</i>
19-Nov-98	Fiji	Air baggage	Baggage, personal effects	<i>Cimex lectularius</i>
02-Feb-99	Unknown	Other methods	Cabin bedding	<i>Cimex hemipterus</i>
21-May-99	India	Air cargo	Wooden Musical Instrument	<i>Cimex</i> sp.
12-Jul-99	Indonesia	Air baggage	Packing paper	<i>Cimex hemipterus</i>
22-Sep-99	Unknown	Other methods	Airport inspection bench	<i>Cimex lectularius</i>
22-Sep-99	Unknown	Air baggage	Airport arrivals hall	<i>Cimex lectularius</i>
28-Sep-99	Fiji	Air baggage	Woven straw fans	<i>Cimex</i> sp.
21-Aug-00	East Timor	Air baggage	Mosquito net	<i>Cimex lectularius</i>
19-Nov-01	Papua New Guinea	Air baggage	Woven cane baskets	Not determined
11-Feb-02	New Zealand	Sea baggage	Baggage, personal effects	<i>Cimex lectularius</i>
20-Feb-02	Asia?	Air baggage	Airline blanket	<i>Cimex hemipterus</i>
26-Apr-02	Papua New Guinea	Air baggage	Woven straw bag	<i>Cimex</i> sp.
25-Jun-02	East Timor	Air baggage	Woven straw mats	<i>Cimex lectularius</i>
20-Aug-02	Yugoslavia	Air baggage	Suitcase lining	<i>Cimex lectularius</i>
25-Oct-02	Italy	Air baggage	Baggage	<i>Cimex hemipterus</i>
14-Dec-02	Papua New Guinea	Air baggage	Woven cane baskets	<i>Cimex lectularius</i>
27-Mar-03	Tonga	Air baggage	Dried Grass	Not determined
12-Nov-03	Turkey	Air baggage	Unknown	Not determined

Notes

¹ From the Pest and Disease Information Database (Market Access and Biosecurity, Department of Agriculture, Fisheries and Forestry), and the Incidents database (Australian Quarantine and Inspection Service).

² This represents the last port of call and may not necessarily be from where the bed bugs were acquired.

³ Identifications were mostly undertaken by Australian Quarantine and Inspection Service Entomologists, where marked 'not determined' the insects were identified as Cimicidae.

Discussion

Clearly, there is currently a major upsurge in bed bug infestations within Australia. The data presented here probably only represent the 'tip of the iceberg' and the Department of Medical Entomology increasingly is receiving calls from hotel owners, hostels and backpacking associations, private residents, as well as other pest controllers reporting an increase in bed bug infestations.

It would appear that most of the bed bug infestations probably have been brought into the country as indicated by the accommodation type most frequently treated. Despite this, some of the infestations have been acquired locally, as the Department does have documented cases of incidences in private homes where the owners have had neither a recent history of overseas travel nor any visitors from other countries.

The interception of bed bugs will always be very difficult as they are a small insect (1-6mm, depending on the stage) and are very elusive in nature. In the event of bed bug detection by AQIS, the goods are treated, re-exported or destroyed (Halling, L. AQIS Entomologist, 2004, *pers. comm.*). There has been much speculation on how bed bugs are spread from country to country (Boase 2001; Krueger 2000), and it would appear from the PDID that most are transported via the baggage of air travellers. This, we believe, is the first attempt to document how bed bugs are spread around the world. It is likely that several of the interceptions where the method of import was not known (such as those on 2 February 1999 and 22 September 1999, Table 1), were from the nature of the interception, probably also through baggage, giving a total of over 82% carried by luggage. The type of goods in which the bed bugs were found varied quite substantially and probably reflects the diversity of items carried by travellers. Woven materials, being of plant origin, are always closely examined by AQIS inspectors and, as they contain many crevices, are likely materials for bed

bugs. It is also not surprising that most of the places of origin (despite these being recorded as the last port of call) were in poorer nations, as these countries did not experience the earlier downturn in bed bug numbers to the extent in more developed nations (Lindsay et al. 1989; Newberry, Mchunu & Cebekhulu 1991; Tonn et al. 1982).

The resurgence in bed bugs is happening in many developed nations. To highlight the increasing global concern regarding bed bugs even further, the Department of Medical Entomology has received email enquiries from around the world. Over the three-year period from 1998 to 2000, 16 bed bug enquiries were received, while from the start of 2001 to May 2004 there were 179. It is also worth noting that on the Department's web site (www.medent.usyd.edu.au) the Bed Bugs Fact Sheet is the most commonly accessed page globally.

There are many explanations for the recent increase in bed bug numbers, although none has been scientifically substantiated (Boase 2001). The rise in international travel is suggested as the main reason, with travellers being more likely to encounter the pest (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). Air conditioning in modern buildings, which has eliminated extreme variations in temperatures, is thought to have allowed bed bugs to become established in some countries (Abul-Hab et al. 1989). There are indications that the trade in second-hand furniture, especially beds, has facilitated the transfer of bed bugs locally, and probably around the world (King 1990). However, no infested furniture has been detected by AQIS since 1986 (the start of the PDID), although as stated, bed bugs are notoriously difficult to detect.

There have been many recent changes in management practices within the pest control industry, benefiting bed bugs. For example, insecticidal treatments of bedrooms are no longer commonly undertaken (Garrards Technical Advisory

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2002). Insect management now targets the control of specific pests, which means that bed bugs are unlikely to be affected incidentally by treatments. For example, cockroach control now relies heavily on toxic baits, rather than broadly acting surface insecticides, and thus bed bugs are no longer exposed to the toxins. When insecticides are used against bug beds, it is the synthetic pyrethroids (SPs) that are mainly employed. It appears that these have a repellent effect and bed bugs can therefore avoid lethal contact. The SPs do not have as long a residual activity as previous chemicals, which means that reinfestations are more likely to occur. Many pest controllers have had little experience in the control of bed bugs and treatment failure is common, largely due to harbourages not being identified during the control process. Compounding this is the omission of bed bugs from the curriculum of many pest control courses in Australia, meaning that knowledge of basic ecology of this pest is often lacking among pest managers. Often the cause of the mysterious bites within a premise is not linked to bed bugs, and misidentification of these pests is known to occur (Falco 1998). Also, control technologies for bed bugs have remained virtually unchanged during the last 30 years (Krueger 2000).

Another possible reason for the recent rise in the incidence of bed bugs is the stigma attached to the reporting of bed bugs by the hospitality industry. If an infestation is reported, the perception is that business might be threatened, and so minor infestations are often ignored or treated in an *ad hoc* manner (King 1990). Ignoring infestations, however, does come with a great risk, notably the possibility of litigation as a result of visitors being bitten. This has now happened; in a landmark case, a motel chain in the United States was successfully sued for \$US382,000 after guests were bitten by bed bugs (*Matthias vs Accor* [Accor Economy Lodging] 2003). Other court cases have followed (Bowles 2003)

and the first author has been involved in local rental disputes over similar incidences. It is only a matter of time before litigation over bed bugs occurs in Australia.

The introduction of the tropical bed bug to Australia (Doggett, Geary & Russell 2003) has probably contributed to the general increase in bed bug infestations. This species prefers a warmer climatic zone than that of the common bed bug, and thus a greater geographical area is at risk of developing an infestation. Currently, the distribution of this species is not known and to date all identified specimens have come from Queensland.

Resistance to insecticides has long been recognised in bed bugs but only recently has this extended to the synthetic pyrethroids (Myamba et al. 2002). This was reported in the tropical bed bug overseas and so treatment failures might well occur here in the future, especially as this group of insecticides is often the preferred choice by pest controllers in Australia. As there have been no local studies of insecticide susceptibility, any resistance might not be recognised for some time and control failure would probably be attributed to other causes.

For the compilation of this report, most state health departments across the country were contacted regarding the apparent rise and, interestingly, very few receive enquiries about bed bugs. This might explain why the dramatic increase has escaped the notice of many health workers and why health authorities have largely not actively responded to the rise of this public health nuisance. With the increase in bed bug numbers, it would be expected that health workers would be called on for advice in the near future.

Finally, with the combination of reduced control pressures and the factors encouraging bed bug dispersal and establishment described above, an exponential increase in this pest might have been expected. This appears to be the situation currently in Australia and other countries around the world.

In light of the dramatic resurgence in bed bugs and the need for health workers to be provided with up to date information, a brief review follows encompassing identification, biology, clinical association and control.

Bed bug biology

Bed bugs are wingless insects, roughly oval in shape, 5-6mm long when fully grown, and are fast runners (Service 1980). They are pale cream in the juvenile stages becoming rust brown as an adult and change to a deeper red brown following a blood meal (see the Department's web site for photographs of live bed bugs: www.medent.usyd.edu.au). Bed bugs are dorsoventrally flattened and can hide in narrow cracks and crevices, making detection often very difficult.

Of the two species, the common bed bug has long been known in Australia, whereas the tropical bed bug was only recently recognised in the country (Doggett, Geary & Russell 2003). The two species are differentiated on the basis of an upturned lateral flange on the thorax of the common bed bug, which is absent in the tropical (Ghuri 1973).

There are five juvenile stages known as nymphs, that are miniature versions of the adults in general appearance. Each nymphal stage requires at least one blood meal to moult to the next stage and it takes 3-5 minutes for complete engorgement to occur. The length of the lifecycle is extremely variable and is dependent on temperature. For example, in cold conditions, they can live for almost two years, even without a blood meal. However, in average conditions of around 23°C, the lifecycle takes around two months to complete and the adult can live for almost 4.5 months (Busvine 1980). All nymphal stages and adults of both sexes require blood for nutrition and development. After mating, each female lays 2-3 eggs a day throughout her lifespan. The cream coloured eggs (1mm in length) are cemented on rough surfaces of hiding places and will hatch within approximately nine days at a room temperature of around

23°C, but take longer in cooler conditions.

The mouthparts of bed bugs are especially adapted for piercing skin and sucking blood. Like most blood sucking arthropods, they inject saliva during feeding, which has anticoagulant properties. Bed bugs respond to the body warmth of a host and quickly locate a suitable feeding site. They tend not to live on humans and the only contact is for a blood meal. Being a cryptic species, blood feeding typically occurs at night, and they tend to seek shelter during the day and become inactive while digesting the blood meal. However, bed bugs are opportunistic and will bite in the day, especially if starved for some time. While their preferred host is human, they will feed on wide variety of other warm-blooded animals including rodents, rabbits, bats and even birds.

Bed bugs shelter in a variety of dark locations, mostly close to where people sleep. These include under mattresses, floorboards, paintings and carpets, behind skirting, in various cracks and crevices of walls, within bed frames and other furniture, and behind loose wallpaper. Bed bugs stay in close contact with each other and heavy infestations are accompanied by a distinctive sweet, sickly smell, akin to that of 'stink bugs' that commonly infest citrus trees. Blood spotting on mattresses, bed linen, nearby furnishings and walls is often a telltale sign of an infestation.

Clinical association

Bed bugs are public health pests largely because of their nuisance biting, and often the most serious health aspect for many individuals is the mental trauma of knowing that there is an infestation. Skin reactions, which are commonly associated with bed bugs, result from the saliva injected during feeding. Some individuals do not react to their bite, whereas others can experience a great deal of discomfort and loss of sleep from the persistent biting. The most commonly affected areas of the body are the arms and shoulders. Reactions to the bites may be delayed; with up to nine days before lesions

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appear (Sansom, Reynolds & Peachey 2003). Common allergic reactions include the development of large wheals, often >1cm, which are accompanied by itching and inflammation. The wheals usually subside to red spots and can last for several days. Bullous eruptions have been reported in association with multiple bed bug bites (Fletcher, Arden-Jones & Hay 2002) and anaphylaxis may occur in patients with severe allergies (*Professional Pest Controller*, 2003, vol. 32, pp.16-7). In India, iron deficiency in infants has been associated with severe infestations (Baumann 2002). It has been suggested that allergens from bed bugs may be associated with asthmatic reactions (Abou et al. 1991; WanZhen & KaiShong 1995), although such studies are limited and require further investigations.

Bed bugs have been suggested for the transmission of a wide variety of infectious agents, although their status as vectors is uncertain (Krueger 2000). It has been proposed that they might play a role in the spread of hepatitis B (Ogston et al. 1979), but this is not supported by epidemiological evidence (Vall Mayans et al. 1994) and attempts to transmit the virus to chimpanzees have been unsuccessful (Jupp et al. 1991). However, hepatitis B DNA can be detected in the faeces of bed bugs for up to six weeks post-feeding on a viraemic blood meal (Silverman et al. 2001) and so the possibility of transmission through contact with contaminated faeces or crushing live bed bugs cannot be excluded (Ogston & London 1980). Despite this, there has never been a single proven case of an infectious agent passed on to humans by bed bugs (Goddard 2003).

Bed Bug Control

To control bed bugs, a careful inspection must be undertaken and all possible hiding places within infested and adjoining rooms examined. Once all likely sources have been identified, an approved insecticide, which has some residual activity, should be applied to all harbourages. The synthetic

pyrethroids are the main chemicals of choice for control in Australia because of their low mammalian toxicity, although the efficacy of different chemicals from this group was found to be highly variable when tested against a laboratory colony of the common bed bug (Fletcher & Axtell 1993). Non-chemical approaches to control involve the use of hot air and/or wrapping up infested articles and furniture in black plastic and placing the articles in the sun, thereby killing the bed bugs with the heat generated, although the latter method may not be effective on larger items such as mattresses. Generally, pesticides will need to be applied in conjunction with any non-chemical means of control. Good housekeeping practices, especially improvements in hygiene standards, and the reduction in possible harbourages such as cracks and crevices will discourage repeat infestations. Metal bed frames provide fewer hiding places than wooden beds and may help to prevent an infestation in a mattress from spreading to other areas of a room. As bed bugs are cryptic in their habits, complete control is often difficult to achieve with one treatment. This is especially so with heavy infestations and thus a post control treatment evaluation is always required.

Conclusion

The global rise of bed bugs early into the 21st century seems to be the culmination of numerous phenomena. Perhaps the most telling of these is the lack of understanding of the ecology and biology of the pest, which is essential for control. This lack of knowledge is probably not surprising; bed bugs had virtually disappeared as a significant pest in the western world for many decades. However, this appears to have now changed and unless the accommodation industry openly acknowledges the extent of the problem, and pest control operators and health professionals gain expertise in recognising infestations and provide the most appropriate management advice, then bed bugs will continue to prosper.



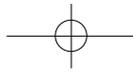
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