Edible insects and other invertebrates in Australia: future prospects

Alan Louey Yen[1]

At the time of European settlement, the relative importance of insects in the diets of Australian Aborigines varied across the continent, reflecting both the availability of edible insects and of other plants and animals as food. The hunter-gatherer lifestyle adopted by the Australian Aborigines, as well as their understanding of the dangers of overexploitation, meant that entomophagy was a sustainable source of food. Over the last 200 years, entomophagy among Australian Aborigines has decreased because of the increasing adoption of European diets, changed social structures and changes in demography.

Entomophagy has not been readily adopted by non-indigenous Australians, although there is an increased interest because of tourism and the development of a boutique cuisine based on indigenous foods (bush tucker). Tourism has adopted the hunter-gatherer model of exploitation in a manner that is probably unsustainable and may result in long-term environmental damage. The need for large numbers of edible insects (not only for the restaurant trade but also as fish bait) has prompted feasibility studies on the commercialization of edible Australian insects. Emphasis has been on the four major groups of edible insects: witjuti *grubs (larvae of the moth family Cossidae),* bardi *grubs (beetle larvae), Bogong moths and honey ants. Many of the edible moth and beetle larvae grow slowly and their larval stages last for two or more years. Attempts at commercialization have been hampered by taxonomic uncertainty of some of the species and the lack of information on their biologies. This has made it difficult to establish rearing facilities that can raise large numbers of edible insects in a short time. Even if effective mass rearing techniques for edible insects can be developed, the next hurdle is overcoming the cultural barriers against consuming insects in Australia. Notwithstanding these problems, there is considerable potential for greater use of insects as human food (either as insects* per se *or as food supplements) or as stock food (especially for poultry and fish). This will result in more energy-efficient food production and facilitate environmental conservation.*

Keywords: Aborigines, animal food, conservation, entomophagy, indigenous food, protein

Entomophagy

At a time when scientists acknowledge the importance and need for ecosystem services provided by insects, western society does not seriously consider them for human consumption. Their small body sizes, difficulty in collection and processing and unpredictability in obtaining large numbers in the wild are major practical impediments **.** There

[1] Biosciences Research Division, Department of Primary Industries, 621 Burwood Highway, Knoxfield, Victoria, Australia 3156. Email: alan.yen@dpi.vic.gov.au

are two main barriers to the acceptance of eating insects: (1) the bad reputation they have as unhygienic and disease-spreading species; and (2) their association with the concept that they are only eaten in times of starvation or as a food source of primitive hunter-gatherer societies (MacEvilly 2000; DeFoliart 1999). There is legislation in some countries regarding insects in food products, ranging from zero tolerance in the United Kingdom to allowing maximum permissible levels in the United States (MacEvilly 2000; Gorham 1979); the basis of this legislation is food contamination and perceived health issues associated with insects (Gorham 1979).

Over 1 500 species of insects are known to be consumed by humans from over 300 ethnic groups in 113 countries (MacEvilly 2000). Most of this entomophagy occurs in central and southern Africa, Asia, Australia and Latin America, and can provide 5 to 10 percent of the annual animal protein consumed by various indigenous groups as well as fat and calories, and various vitamins (A, B_1, B_2 and D) and minerals (iron, calcium) (Gullan and Cranston 2005; MacEvilly 2000).

Entomophagy and the Australian Aborigines

Until European settlement, Aborigines lived as nomadic hunter-gatherers. Survival required a comprehensive knowledge of the flora and fauna and their responses to varying geographic and climatic conditions (O'Dea 1991). They consumed a varied diet in which plants provided fibre but animal foods predominated. This diet was not high in fat as the meat was lean most of the year. Most food was either eaten raw, roasted on ashes, or baked whole in an earth oven. Most Aborigines lived in bands based on extended family groups (20 to 30 individuals) and there were larger gatherings for traditional ceremonies when there was sufficient food available to support larger numbers. Examples included men gathering in the Alps of southeastern Australia during summer to feast on Bogong moths (Flood 1980) and groups meeting at Waikerie on the River Murray in South Australia to collect adult giant swift moths (*Tricenta argentata*) that emerge in autumn after rain (South Australian Museum, n.d.). Men and women contributed differently; women provided subsistence diet (plants, honey, eggs, small vertebrates, invertebrates) and men were primarily hunters of larger vertebrates. Hunting and gathering was time-consuming, and there was generally only one main meal late in the afternoon after a day of hunting or gathering (O'Dea 1991).

Traditionally, Aborigines in Central Australia of different language groups considered the honey ant an important object of ritual and ceremony, and they were linked by the song cycles and ceremonies associated with it (Devitt 1986). The search and excavation for honey ants involve much time for relatively little return (Devitt 1986), and it was an important group activity for women and children who learned about and *looked after their country*.

Information on entomophagy among the various groups of Australian Aborigines has been summarized by Yen (2005), Meyer-Rochow (2005, 1975), Defoliart (2002), Tindale (1966), Reim (1962), Bodenheimer (1951), McKeown (1936) and Campbell (1926). The information is very patchy and has been confused by linguistic issues, incorrect recording of information, traditional beliefs of the Aborigines, incorrect use of common and scientific names of insects and lack of information on the biology and distribution of most species (Yen 2005). This has resulted in more detailed information about entomophagy among Australian Aborigines

involving a small number of charismatic species (or species groups): *witjuti* grubs, *bardi* grubs, honey ants, *Bogong* moths and sugar bags (native bees).

The common names of some of these insects are based on Aboriginal names. As there are 270 different Aboriginal languages with 600 to 700 dialects in Australia (Australian Info International 1989), this has led to much confusion and different spellings. For example, the name *witjuti* grubs (also spelled *witchetty* or *witchety*) is derived from the Pitjantjatjara name for *Acacia kempeana*, but it has now been loosely applied to many edible grubs across Australia. Among the Arerrnte, the same species is known as *tyape atnyematye*, with *tyape* indicating edible grub, *atneyeme* is the *witchetty* bush and *atnyematye* is the grub from the root of the *witchetty* bush (Central Land Council 2007b). The name *bardi* grubs is based on a buprestid beetle from *Xanthorrhoea* in southwestern Western Australia, but has also been loosely applied to edible grubs across Australia. Some Aboriginal groups had a better naming system for edible grubs: they used a term for *edible grub*, such as *maku* in Pitjantjatjara, followed by the name of the plant (Yen *et al.* 1997). Hence the edible grub from *Acacia kempeana* is known as *maku witjuti* among Pitjantjatjara speakers or *tyape atnyematye* by the Arrernte (Plate 1).

Plate 1. Witjuti grub from Central Australia *(Courtesy A.L. Yen)*

An important question is whether the information we have available today is an accurate reflection of the full range of insects (and other invertebrates) eaten by Australian Aborigines. Other edible insects may not have been recorded in the literature. In addition, there is the question of why groups of insects eaten by other indigenous groups outside of Australia were apparently not favoured in Australia. For example, termites (Isoptera), leaf-feeding caterpillars (Lepidoptera) and grasshoppers (Orthoptera) are major components of insect diets in most

other continents (Banjo *et al.* 2006b; DeFoliart 2005; Malaisse 2005; FAO Département des Forêts 2004; Paoletti *et al.* 2003; Bodenheimer 1951), but only figure as minor items in a few Australian records (Meyer-Rochow and Changkija 1997; Meyer-Rochow 1975; Reim 1962).

To better understand entomophagy in Australia, it is important to consider the Australian environment and how it was exploited by the Aborigines before European settlement. Australia is an arid continent with soils poor in nutrients, unpredictable availability of water (droughts and floods) and wildfire hazards. The unpredictable climatic patterns result in a huge variation in plant species composition and reproduction, and population fluctuations of animals, leading to opportunistic and flexible activities that resulted in the seasonal movements of Aborigines (Allen 1974). There was no cultivation of grain and little agriculture as we know it (O'Dea 1991). The main habitat manipulation to increase plant production was controlled mosaic burning or *fire-stick farming* (Jones 1980).

The Australian environment is dominated by two plant genera, *Eucalyptus* and *Acacia*. This has resulted in enormous diversification of several families of insects (Yen 2002), and may be one reason for the absence of leaf-feeding caterpillars in the diet of Australian Aborigines. Many of the larger species feed on eucalypts and the oils and other chemicals in the eucalypt leaves make the caterpillars unpalatable. The major factor is climate unpredictability resulting in enormous variation in occurrence and abundance of insects. Many insects have long periods of relative inactivity or have well-protected immature life history stages; some have long life cycles, followed by mass emergence at times of adequate resources.

The nutritional value of insects to the pre-European settlement Aboriginal diet has received relatively little attention compared to the contribution of larger vertebrates. For many years, even the value of plants in the diet has been underestimated and only in recent years has this matter been addressed. With insects, more information is required about the role of entomophagy in traditional diets. It is difficult to generalize about the diet of Aborigines because it would have varied considerably across the continent, which is generally semi-arid or arid but with subtropical environments in the north and temperate conditions in the east, southeast and southwest. The insect diets would have reflected availability and need. Did entomophagy represent a need for proteins, fats and other substances of animal origin? How much of entomophagy is due to food deficiency (protein) or to tradition? It has to be remembered that Australian Aborigines ate their food raw, roasted on ashes, or baked in ashes. They did not use cooking utensils (except wrapping food in leaves or bark in northern Australia), and there was a lack of herbs and spices. The current indication is that insects provided sugar (honey ants, sugar bags, lerps) and fat (grubs, *Bogong* moths), although *witjuti* grubs have 38 percent protein and nearly 40 percent fat (a composition similar to olive oil [Naughton *et al.* 1986 in O'Dea 1991]). Native bees and honey ants were important seasonal sources of carbohydrates (Plate 2). Interestingly, Orthoptera are rich in proteins but were not eaten widely in Australia. Bukkens (2005) summarized nutrient aspects of insects for human diet around the world, but detailed information from Australia is lacking. Rich (2006 citing Miller *et al.* 1993) provided information on the nutritional value of raw and cooked *witjuti* grubs (species not cited) and the abdomen of *Bogong* moths.

The importance of insects in the diets of Australian Aborigines varied across the continent before European settlement, reflecting both the availability of edible insects and of other plants and animals as food. The hunter-gatherer life style adopted by the Australian

Aborigines involved patterns of movement determined by resource availability, and this, combined with low population numbers, reduced the danger of overexploitation of food resources.

Plate 2. Honey ants *(Courtesy R. Start)*

Current status of entomophagy in Australia

Over the last 200 years, entomophagy among Australian Aborigines has decreased because of the increasing adoption of European diets, changed social structures and changes in demography.

Entomophagy has not been readily adopted by non-indigenous Australians, although there is an increased interest because of tourism and the development of a boutique cuisine based on indigenous foods (bush tucker). Tourism has generally adopted the hunter-gatherer model of exploitation in a manner that is probably unsustainable and may result in long-term environmental damage. The exceptions are (1) promotion of iconic Aboriginal insect foods (*witjuti* and *bardi* grubs, honey ants) either as a boutique cuisine or part of a bush tucker tourism experience; (2) use of freshwater and burrowing crayfish as food items in their own right; (3) farming of exotic garden snails (*Helix aspera*) for restaurants; (4) insects, crayfish and earthworms (both native and introduced species) as recreational fish bait; and (5) insects bred as pet food (primarily for reptiles). Except for the first category, indigenous Australians are rarely associated with these activities.

There is a small industry in Australia that breeds the exotic snail *Helix aspera* for the restaurant trade and for personal consumption. There have been government-funded

feasibility studies on this snail (Murphy 2001; Begg 2006, 2003). Snails are reared and purged on a high fibre diet before processing. They are sometimes cooked, de-shelled and sold bottled. Regulatory authorities in Australia face a dilemma in that on the one hand, they want to encourage the development of alternative farm products such as snails, yet on the other hand, they need to protect existing industries (such as crops) from pest snails. Teo (2004) gives an example of the adverse environmental effects of a snail introduced to provide protein but escaping and becoming a crop pest. The same issue applies to the breeding of exotic earthworm species that are sold to gardeners and farmers.

Recreational fishing is a major industry in Australia, and there is a wealth of information on the use of live insects and other invertebrates (freshwater crayfish and earthworms) as bait, in fishing magazines and on fishing organization Web pages. While the information is interesting, some of it is full of errors and biases. Recreational anglers generally use fresh insect bait, and there is a preference in temperate Australia for what are incorrectly call *bardi* grubs found in the ground under River Red Gums. These are in fact hepialid moth larvae, more akin to *witjuti* grubs. They are dug up, stored separately (or else they can damage each other) either in the refrigerator or they are blanched in milk and frozen. They are sold for A$1.50-2.50 each.

These activities have environmental and social consequences. The wild harvests of *witjuti* and *bardi* grubs and honey ants were sustainable activities when small numbers of traditional owners traveled by foot and collected them at appropriate times of the year. Today, tourism companies take bus loads of visitors to dig up edible insects. Some of these tourism ventures are led by traditional owners. However, the sustainability of a tourism-driven market using motor vehicles to access food has to be determined. Large numbers of recreational anglers digging up *bardi* grubs, in conjunction with other threats to forests (inappropriate forestry, fuelwood collection, eucalypt dieback due to changed hydrological regimes, cattle grazing, to name a few) could threaten the long-term viability of these grubs. There are now artificial grubs available, including a mould to make a *bardi* grub out of soft cheese!

Commercialization issues

The need for large numbers of edible insects (not only for the restaurant trade but also as fish bait) has prompted feasibility studies on the commercialization of edible Australian insects. Emphasis has been on the four major groups of native edible insects: *witjuti* grubs (larvae of the moth family Cossidae), *bardi* grubs (beetle larvae), *Bogong* moths and honey ants (Rich 2006), and the exotic snail *Helix aspera* (Berg 2006, 2003). Many of the edible moth and beetle larvae grow slowly and their larval stages last for two or more years. Attempts at commercialization, either by wild harvest or by mass rearing, have been hampered by taxonomic uncertainty of some of the species and the lack of information on their biologies. The small sizes of insects make collection or rearing and processing difficult; in the wild their locations and population numbers are unpredictable. This has made it difficult to establish rearing facilities that can raise large numbers in a short time.

Large-scale harvest or production of insects for human consumption has several issues that have to be considered, including the practicality of collecting from the wild and the possibility of overharvesting, economic mass rearing techniques, preservation and storage of the products and marketing.

Despite these issues, it has to be remembered that many invertebrates are unsafe to eat; some are inedible while others may initiate allergic reactions among humans (Gullan and Cranston 2005; MacEvilly 2000; Phillips and Burkholder 1995; Blum 1994; Berenbaum 1993), although this equally applies to all other plant and animal foods. Although many insects contain toxic chemicals, there are few records of harm to humans (Gorham 1979). Insects may also contain pathogenic microbes as a result of improper processing or handling, just like all food products, and preventive measures need to be in place (Banjo *et al.* 2006a).

Collecting (harvesting)

Most edible insects are harvested from the wild (DeFoliart 1995). The availability of edible insects in Australia is unpredictable, both in time and location. There are suggestions that wild harvesting of crop pests is a possibility (Banjo *et al.* 2006) and that this can also reduce pesticide use (DeFoliart 2005; Gullan and Cranston 2005). There is another aspect, as some insects may contain higher than acceptable levels of chemicals (as will be discussed with *Bogong* moths later). In Australia, the major mobile plant pest is the Australian plague locust, *Chortoicetes terminifera* (Hunter 2004), although Schulz (1891) reported that the Aborigines around the Finke River region would not eat them.

Better management of sustainable harvesting of wild populations and more dependable supplies based on economically feasible mass rearing will only be possible in Australia with more information about the biology of edible species. This will require involving indigenous groups to participate and benefit from the exercise.

Mass rearing

Rich (2006) examined the feasibility of establishing a closed production system facility to rear *witjuti* grubs commercially under controlled conditions. The proposed method involved: (1) sourcing a generic pool from the wild; (2) rearing larvae through to adults; (3) getting adults to mate; (4) female oviposition and eggs transferred to bark crevices in containers (each female may carry up to 20 000 eggs); (5) egg hatching; (6) caterpillars maintained and farmed when they have grown to up to 15 centimetres in length. Rich (2006) defined *witjuti* grubs as moths in the Cossidae family (wood moths with stem-boring or root-feeding larvae) of which there are over 100 species in Australia (Common 1990), hepialid moth larvae and some beetle larvae.

The life cycle of wood moths takes over two years (Monteith 2006). The question has been raised as to whether the life cycle can be hastened by diet using synthetic diets or semi-synthetic diets such as those used for the hepialid *Wiseana copularis* in New Zealand (Allan *et al*. 2002). Even the life history of well-known species such as the giant wood moth (*Endoxyla cinerea*) is not completely understood; although later stage caterpillars live in trunks, the biology of younger stages is not known and they may be root feeders (Monteith 2006). Dann (2003) inadvertently reared two *bardi* grubs through to pupation by keeping them in sawdust, indicating that a fully functional trunk may not be required for their survival.

To fully utilize mass insect rearing facilities, Rich (2006) suggested supplementary production activity of other insects such as *Bardistus cibarius* (*bardi* grub), honey ants, and the *Bogong* moth (*Agrotis infusa*). *Bardi* grub rearing would be suitable for the protocol outlined by Rich (2006); however, the other two species have their own unique biological characteristics that could make mass rearing a challenge.

The honey ant (*Melophorus bagoti*) is a social species that relies on two other biological components for successful production of honey by the repletes: its host *mulga* trees (*Acacia aneura*) and the scale insect *Austrotachardia acaciae* (Latz 1995). The honey ant workers collect honeydew from the scale insect to feed the repletes. Keeping social species like ants in captivity for food production can be difficult and the output is low compared to the commercial honey bee (*Apis mellifera*); individual honey ant nests rarely supply more than 100 grams of honey, comparable to commercial honey (Gullan and Cranston 2005). In Australia, other ant species have been maintained in culture for either venom research or as a source of chemicals such as antibiotics (Beattie 1994); these efforts may provide useful information on mass rearing for edible ants.

The *Bogong* moth is characterized by adult flight involving distances of more than 1 000 kilometres that may be necessary for breeding. Their life cycle is about six to seven months (eggs to adult). The main breeding grounds are pastures west of the Dividing Range and adults fly to the Southern Alps for the summer (Common 1954). The Aborigines (generally men) collected adults in the Alps, cooked and ate the bodies (over 60 percent of which is fat) or ground them into cakes for storage (Flood 1980). The *Bogong* moth can be an agricultural pest, but it faces several threats itself: loss of summer alpine habitat (cattle-grazing, wildfire, climate change) and accumulation of arsenic from agricultural sprays such as the herbicide monosodium methylarsenate. While individual moths have low arsenic content, accumulation from large numbers of moths has resulted in high arsenic levels in alpine soils at summer sites. Furthermore, the *Bogong* moths are a main food item of the endangered mountain pygmy possum (*Burramys parvus*) (Green *et al.* 2001).

There are over 100 species of freshwater crayfish in Australia, including the world's largest species, *Astacopsis gouldi* from Tasmania which reaches weights up to 4.5 kilograms (Short 2000). Some species, for example the burrowing crayfish (*Engaeus* species), are actually terrestrial but live in subterranean cavities full of water, while others live in freshwater bodies (*Cherax*, *Euastacus*, *Astacopsis*). Australian Aborigines ate the yabby (*Cherax destructor*) (Gillon and Knight 1986), and it has been suggested that they translocated this species into central Australia (Horwitz and Knott 1995). Australia currently has three species that are commercially exploited for the food industry: the yabby (*Cherax destructor*), redclaw (*C. quadricarinatus*) and marron (*C. tenuimanus*). The yabby naturally occurs in southeastern Australia, but the main production output is from populations translocated to southwestern Australia. Redclaw is produced in Queensland and northern New South Wales. The marron occurs in southwestern Western Australia but has been translocated to South Australia for production. Both redclaw and marron are bred in aquaculture facilities, while yabbies are mainly harvested from farm dams. From 1996 to 1999, production of these three species in Australia amounted to 421 tonnes (valued at approximately A$5 million), and the projected output in 2004/2005 was 1 589 tonnes (Piper 2000). Many of the burrowing and freshwater crayfish are restricted in their distribution, and several threatened species are listed (O'Brien 2007).

Preservation and storage

The mass rearing of insects for consumption or sustainable harvesting from the wild is an important hurdle that needs to be overcome. Australian Aborigines generally ate the food they collected or caught on the same day or not long after. There are only a few recorded examples of Aborigines preserving insect food to eat later. These include making *Bogong* moths into a cake (Flood 1980), a caterpillar (could be *muluru* of the Wangkangurru and Yarluyandi people or *anumara* of the Arrente people) that fed on grass that had its head pulled off, its body contents squeezed out and the body dried in hot ashes and was either eaten or stored (Hercus 1989; Kimber 1984) and collection of psyllid lerps from eucalypt leaves (Plate 3) that were rolled into a ball that could be stored for months (Central Land Council 2007b; Bin Salleh 1997). The *ayeparenye* caterpillar feeds on tar vine (*Boerhavis* spp.) and was collected in large numbers and gutted (*werlaneme*) and cooked in hot ash; it can also be stored (Central Land Council 2007b). *Witjuti* grubs that are dug out from inside a piece of *Acacia kempeana* root will seal up the exposed ends of the root and they can be kept alive for several days and transported within the root (author, personal observation).

Plate 3. Lerps or sweet secretions of psyllid bug nymphs *(Courtesy A.L. Yen)*

The storage and transport of fresh insects is a problem if large distances are involved, while dried, canned or bottled specimens are common (Ramos-Elorduy 2005). With modern food preservation methods such as freeze drying and cryovacking, long-term storage for transport should not be a major problem. If international export of insects is to be considered, one

important issue that requires consideration is the contamination level of the insects, which may breach quarantine regulations in different countries.

Marketing

Possibly the most difficult task in expanding the value of entomophagy is getting people to accept the practice. The shunning of entomophagy is primarily cultural (Gullan and Cranston 2005). The first step is to counter western bias against insects as food; this strong public bias in the west also influences perceptions of entomophagy in traditional societies (Morris 2004). The issues that need to be considered are whether people in western societies will eat insects and whether they will aid developing nations that may need to mass produce insects as food.

In Australia, a market evaluation survey indicated that the idea of consuming *witjuti* grubs was a challenge for nearly half the 1 273 people interviewed; 33 percent were neutral, and only 20 percent considered them acceptable (Rich 2006).

People need to be given reasons why insects should be eaten other than the fact that they play a crucial role in diets of many peoples (Morris 2004). The messages should be that: (1) most insects have high food conversion efficiency compared with conventional livestock (Gullan and Cranston 2005); (2) cultivating insects for protein is less environmentally damaging than cattle ranching; (3) minilivestock (insect farming) can be a low-input, sustainable form of agriculture (Gullan and Cranston 2005);[2] and (4) semi-domestication of invertebrates could reduce pressures on natural populations (Paoletti and Dreon 2005; Paoletti and Dufour 2002).

The ways in which insects are eaten also need to be addressed. They can be eaten by people directly (either insects *per se* or insect additives to food), or indirectly by having them in the food production chain.

Eating insects whole or their body parts can be difficult for those brought up in western societies. This is overcome by presentation (mixing insects into more complex dishes) or by comparing them to currently accepted food types (especially crustaceans). If we are seeking to include insects for nutritional reasons, then perhaps we should consider the addition of ground-up insects in prepared foods (such as flour or pastes). This raises the question of whether we simply farm known species such as silkworms (*Bombyx mori*), house flies (*Musca domestica*) and mealworms (*Tenebrio monitor*). The answer is that we probably need to find out what other insects can provide that these species do not.

Insects and other invertebrates such as earthworms can be an important food for domesticated animals, and there are many examples of where they are used as feed for fish, poultry and pigs (Oyegoke *et al.* 2006; Gullan and Cranston 2005). The earthworm *Eisenia fetida* fed to

[2] Insects could provide alternative forms of income to current production farms and involve much less land. In a study on the feasibility of commercializing bush food plants in Queensland, Phelps (1997) found that there was less interest while income from more traditional forms of farming was greater.

aquarium fish (*Poecilia reticulata*) resulted in significantly increased brood numbers (double) compared to standard food (Kostecka and Paczka 2006).

The future: entomophagy and conservation in Australia

What are the main requirements if entomophagy is to be advocated as a serious option for Australia? They involve advocacy (DeFoliart 1989); more attention to the biological potential of edible forest insects, including conservation, forest management, agriculture, nutrition and processing and storage (includes inventory of species); and stakeholder involvement (Vantomme *et al.* 2004).

Advocates

Advocacy for entomophagy needs a concerted effort (DeFoliart 1989). This can be at several levels involving: (1) scientists and conservationists on the potential benefits of entomophagy from an energy and conservation perspective; (2) nutritionalists on dietary advantages; and (3) farmers to establish minilivestock activities. A clear message needs to be delivered that entomophagy is not simply a developing world phenomenon, and developed nations can benefit if it is more widely adopted.

It could be a three-pronged advocacy strategy: (1) promoting iconic species as food for direct human consumption (*witjuti* and *bardi* grubs, yabbies, honey ants, etc); (2) allowing insects as food additives for provision of protein and other nutrients; and (3) encouraging the use of insects as animal (poultry, pig and fish) food.

Museums and zoos could play an important role as advocates. Live invertebrate displays are paramount in improving the profile of “creepy-crawlies” (Yen 1993) and many of these displays have associated captive breeding. This is an opportunity to study the biology of edible species and promote the use of edible invertebrates.

More information on edible insects

An up-to-date inventory of entomophagous insects in Australia is required. This will involve both working with traditional landowners to obtain more information on which species they consider edible as well as information on their biology, collecting, preservation and cooking techniques. Research is also needed on the potential of species that are not eaten by traditional landowners.

Agreement is needed on definitions of scientific and common names for edible insects. As Yen *et al.* (1997) indicated, some Aboriginal groups have more accurate naming systems for edible grubs than those used by scientists. This situation is due to insufficient study on the taxonomy and distribution of these species. However, entomologists need to provide the lead on using correct names (such as *witjuti* and *bardi* grubs); the guide for the official common names of Australian insects (Naumann 1993) lists three taxa of insects as *bardi* grubs: the hepialid moths *Trictena atripalpis* and *Abantiades* `marcidus` and cerambycid beetles; the

term should only be applied to beetle larvae and strictly to the buprestid *Bardistus cibarius* (Yen 2005).

Involvement of stakeholders

There are four groups of stakeholders that need to have active involvement: (1) traditional owners; (2) landowners (whether government or private); (3) industry (food production, processing and marketing; and (4) consumers (Charnley *et al*. 2007).

With regard to the traditional Australian Aboriginal owners, there is an urgent need to document information and traditional stories because the loss of local knowledge is a major issue (Paoletti and Dreon 2005). This information is being lost with the passing of the current generation of elders and often the information is not being handed on to the next generations.

It is not simply a matter of recording the information because traditional knowledge is a complex mixture of language and custodianship (initiated and uninitiated; men and women; and the custodians of knowledge for a particular area). There have been attempts to document insect names among Australian Aborigines (Yen *et al.* 1997; Meyer-Rochow 1975), and the Aborigines themselves have provided much information on the species that they eat (Central Land Council 2007b; Dann 2003; Goddard and Kalotas 2002; Bryce 1998; Bin Salleh 1997; Latz 1995; Turner 1994; Hercus 1989; Devitt 1986; Gillon and Knight 1986).

There are often deeper meanings to names and ceremonies that involve restricted knowledge associated with looking after the land or with growing up. For example, some Central Australian songs and dances about *witjuti* grubs may refer to more complex social issues related to growing up and marriage (Roheim 1933). In another example, Spencer and Gillen (1899) described a *witchetty* grub ceremony at Emily Gap near Alice Springs in Central Australia. But the site is not known for the grub that feeds in the roots of the *witjuti* bush (*Acacia kempeana*). Instead, Emily Gap is a very important location for the traditional Arrernte owners because it is where *arlperenye* (the green stink beetle) decapitated the *ayeparenye* (the caterpillar that feeds on tar vine, *Boerhavis* spp), *ntyarlke* (the caterpillar that feeds on pigweed, *Portulaca olearacea*) and *utnerrengatye* (the caterpillar that feeds on the emu bush, *Eremophila longifolia*), and spilled their innards everywhere. It is the place where the caterpillars that are considered the main creative ancestors of Alice Springs originated (Central Land Council 2007a,b). These three caterpillars were food items and were ritually gutted before eating. A hole was dug and the guts were squeezed into the hole and buried; this gutting process is called *werlaneme* and had to be done according to Arrernte Law because these *tyape* (edible caterpillars) were very sacred to the area and the Arrernte people (Central Land Council 2007b). Interestingly, the scientific identities of these three species are still uncertain.

Documenting information from traditional owners requires acknowledgement that some sensitive information cannot be made public. For example, information on whether a particular insect is edible and how it is collected is often forthcoming, but information on Aboriginal understanding of the biology and mythology (which can be associated with creation and movement across the country) may not be.

Consultation with Aboriginal communities is essential because they will, in many cases, have important information on edible insects, may retain some ownership of land involved and they could be an important contribution to small local economies (Vantomme *et al*. 2004). Aboriginal involvement would involve gaining community support, provision of training, support services (developing a business plan, funding, site selection, species and plant), marketing and issues associated with intellectual and cultural property (Miers 2004).

Controlled mass production including economical mass harvest methods

Two factors work against mass harvest of edible insects from the wild in Australia: unreliability of supply and the potential for habitat destruction. As outlined earlier, Australian Aborigines were able to utilize edible insects in a sustainable manner because of low population densities and tracking resources by moving across the country. There are questions as to whether harvesting for tourism and restaurants is sustainable because motorized transport has increased the area that is searched for food and at a much higher rate. There is unsubstantiated anecdotal evidence that sugarbags (native bees) have declined in the southern parts of Australia; whether this is due to better access or due to other environmental factors, remains to be determined.

The mass harvesting of pest insects is another matter. Whether this is economically feasible needs to be addressed. Pest outbreaks can also be unpredictable, and the mode of collection will depend on the target species. Collecting plague locusts would be difficult because of the vast areas that they cross in a short time, and access to some of these areas can be difficult. Locust control in Australia is based on spraying hopper beds to reduce adult numbers, and this may prevent collection of adults. Some pests of agricultural crops or horticulture could be mass collected by light or chemical (pheromone) traps. Initially it would be necessary to determine if these species are of entomophagous value to humans.

There has been limited study on mass rearing of edible Australian insects (Rich 2006), and the techniques are better developed for snails (Berg 2006, 2003) and crayfish (Piper 2000). There is certainly an opportunity to research mass rearing of selected insects other than the known iconic species as well as determining more efficient ways of rearing *bardi* and *witjuti* grubs. This research needs to be conducted in conjunction with research on food quality and safety. While discussion has focused on using the products within Australia, the value of international export markets needs to be kept in mind.

If minilivestock enterprises are to be established in Australia, it is necessary to consider the design, location and integration of these enterprises with other production systems. These need to be considered in relation to their purpose and how they operate (for example recycling systems for converting organic wastes into high protein feed supplements for humans, poultry, pigs and fish), and how farmers could augment their main income with minilivestock operations. New ventures should be considered, such as the possibility of using appropriate

termites to produce compost from sawmill waste in certain locations, and at the same time harvest termites as animal feed (D. Ewart, personal communication, 2008).

Conservation

Besides reliability of supply, the other main argument for developing mass rearing facilities for edible insects is habitat conservation. While much of Australia is semi-arid or arid (but still with considerable vegetative cover), forests and woodlands have been severely depleted since European settlement. Many woodlands were cleared for agriculture, while some of the remaining forests are still used for timber production. The major threats to Australian forests and woodlands include alienation and fragmentation, altered hydrology regimes, stock grazing and other forms of activities that affect the understorey and ground layers and inappropriate fire regimes.

A survey of entomophagy in Central Africa found that forest caterpillars (Lepidoptera) and grubs (Coleoptera) provided high nutritive value and were a main source of protein, and unlike those from agricultural land, they were free of pesticides. Gathering (by hand or chopping off branches or felling trees) was probably not as much of a threat as logging, bushfires or other forms of forest disturbance (FAO Département des Forêts 2004). The situation in Australia is different in that more forest has been cleared or alienated than in Central Africa, and although not many insects are being harvested, the effects (especially digging for fish bait) could be quite severe. Also, unlike Central Africa, Australian commercial forests are sometimes sprayed with chemicals (insecticides, fungicides and herbicides).

Mass rearing of insects, even if it is only for recreational fishing, would help the conservation of Australian forests. As part of environmental restoration in Australia, there are numerous tree-planting programmes to replace lost forests (and also part of carbon-trading schemes). These programmes range from those with purely conservation goals (planting endemic species with a structure that imitates natural conditions) to purely commercial agroforests. There is a need to consider whether some of these programmes can be integrated into a system that will also involve the production of edible insects.

Conclusions and recommendations

The consumption of insects is not a major component of diet in Australia today. It is confined to some groups of Aborigines (where it is in decline due to preference for processed western foods), as part of the bush tucker tourism experience and in a very small number of restaurants. There are commercial operations involving the mass rearing of freshwater crayfish and *Helix aspera* for human consumption. There is high demand for edible insects as bait in recreational fishing.

There are enormous opportunities to develop and expand entomophagy in Australia on three levels: (1) human consumption of selected species; (2) as a nutritive supplement in food for humans; and (3) as food for fish, poultry and other animals. Most edible Australian insects are difficult to collect in large numbers (and often in isolated locations that make transport to

markets an issue), are unpredictable in their occurrence and inappropriate harvesting could result in significant damage to both their population numbers and their habitats.

Mass rearing of edible insects would be the most appropriate solution to increase their availability. This involves research in raising insects from different habitats (leaf feeders, wood and root feeders, honeydew feeders, etc.) and species that can be highly mobile (for example *Bogong* moths). Mass rearing and preparation of edible insects is a research area that could facilitate more cross-continental collaboration. For example, the Asmat in Papua rear the palm weevil (*Rhynchophorus ferrugineus*) in rotting trunks of sago palm to enable the collection of large quantities (Paoletti 1995); can this idea be applied to edible trunk and root grubs in Australia?

If wild harvesting of edible insects and other invertebrates is to be undertaken, then there needs to be further research on the distribution and population dynamics of these groups so they can be harvested without destroying forests and other environments (Paoletti *et al.* 2000; Paoletti 1995).

The list of widely adopted edible insects in Australia is relatively small (for example *witjuti* and *bardi* grubs, *Bogong* moths, honey ants). This is partly due to taxonomic impediments and the actual number of species of Lepidopteran and Coleopteran larvae eaten (at the moment collectively lumped into the *witjuti* and *bardi* categories) could be quite large. There is an urgent need to document further information from Australian Aborigines because this disappearing traditional local knowledge could be lost forever (Paoletti *et al.* 2000). There could be more edible species in Australia, and it is necessary to learn how the various Aboriginal groups found, collected and cooked them.

Acknowledgements

The author wishes to thank the FAO Regional Office for Asia and the Pacific for the opportunity and assistance to attend the “Forest Insects as Food: Humans Bite Back” workshop in Chiang Mai, Thailand. Thank you to Patrick Durst (Senior Forestry Officer), Dennis Johnson and staff of the Forest Restoration Research Unit of Chiang Mai University.

Literature cited

Allan, R.A., Wang, Q., Jiménez-Pérez, A. & Davis, L.K. 2002. *Wiseana copularis* larvae (Hepialidae: Lepidoptera): Laboratory rearing procedures and effect of temperature on survival. *New Zealand Journal of Agricultural Research*, 45: 71-75.

Allen, H. 1974. The Bagundji of the Darling Basin: cereal gatherers in an uncertain Environment. *World Archaeology*, 5(3): 309-322.

Australian Info International. 1989. *Australian aboriginal culture*. Canberra, Australian Government Publishing Service.

Banjo, A.D., Lawal, O.A. & Adeyemi, A.J. 2006a. The microbial fauna associated with the larvae of *Oryctes Monocerus. Journal of Applied Sciences Research*, 2(11): 837-843.

Banjo, A.D., Lawal, O.A. & Songonuga, E.A. 2006b. The nutritional value of fourteen species of edible insects in Southwestern Nigeria. *African Journal of Biotechnology*, 5(3): 298-301.

Beattie, A.J. 1994. Invertebrates as economic resources. *Memoirs of the Queensland Museum*, 36(1): 7-11.

Begg, S. 2006. *Free-range snail farming in Australia.* A report for the Rural Industries Research and Development Corporation. RIRDC Project No SFI-1A. RIRDC Publication No 06/104. 50 pp.

Begg, S. 2003. *Farming edible snails – lessons from Italy.* Report for the Rural Industries Research & Development Corporation for RIRDC Project Number: SF1-1A. RIRDC Publication Number 03/137. 20 pp.

Berenbaum, M.R. 1993. Sequestered plant toxins and insect palability. *The Food Insects Newsletter*, 6(3). 7 pp.

Bin Salleh, R., ed. 1997. *Mayi: some bush fruits of the West Kimberley*. 2nd ed. Broome, Magabala Books.

Blum, M.S. 1994. The limits of entomophagy: a discretionary gourmand in a world of toxic insects. *The Food Insects Newsletter*, 7(2). 13 pp.

Bodenheimer, F.S. 1951. *Insects as human food*. The Hague, Dr. W. Junk.

Bryce, S., comp. 1998. *Women's gathering and hunting in the Pitjantjatjara Homelands.* Alice Springs, Institute for Aboriginal Development.

Bukkens, S,G.F. 2005. Insects in the human diet: nutritional aspects. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 545-577. Enfield, NH, USA, Science Pub.

Campbell, T.G. 1926. Insect foods of the Aborigines. *Australian Museum Magazine*, 2: 407-410.

Central Land Council. 2007a. *Joint management/national parks. Traditional owners sharing knowledge. Apmere Apwerte Urrthe-arenye Kenhe/the country of the Limestone People. Part 1. Anthwerrke (Emily Gap) and Akapulye (Jessie Gap) Nature Park and surrounding areas.* http://www.clc.org.au/OurLand/land_management/reports/report1-b-limestone.asp

Central Land Council. 2007b. *Joint management/national parks. Traditional owners sharing knowledge. Apmere Apwerte Urrthe-arenye Kenhe/the country of the Limestone People. Part 2. Plants.* http://www.clc.org.au/OurLand/land_management/reports/report1-b-limestone.asp

Charnley, S., Fischer, A.P. & Jones, E.T. 2007. Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. *Forest Ecology and Management*, 246: 14-28.

Cherikoff, V. 1989. *The bushfood handbook*. Bornia Park, New South Wales, Cherikoff Pty Ltd.

Common, I.F.B. 1990. *Moths of Australia*. Melbourne University Press, Carlton.

Dann, D. 2003. *Waranygu Bayalgu [digging for food]*. Geraldton, The Yamaji Language Centre.

DeFoliart, G.R. 2005. Overview of role of edible insects in preserving biodiversity. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 123-140. Enfield, NH, USA, Science Pub.

De Foliart, G.R. 2002. Oceania: Australia. *In The human use of insects as a food resource: a bibliographic account in progress, pp. 1-51.* Chapter 28.

DeFoliart, G.R. 1999. Insects as food: why the western attitude is important. *Annual Review of Entomology*, 44: 21-50.

DeFoliart, G.R. 1995. Edible insects as minilivestock. *Biodiversity and Conservation*, 4: 306-321.

DeFoliart, G.R. 1989. The human use of insects as food and as animal feed. *Bulletin of the Entomological Society of America*, 35: 22-35.

Devitt, J. 1986. A taste for honey: aborigines and the collection of ants associated with mulga in Central Australia. In P.S. Sattler, ed. *The Mulga lands*, pp. 40-44. Brisbane, Royal Society of Queensland.

Flood, J. 1980. *The moth hunters*. Canberra, Australian Institute of Aboriginal Studies.

FAO Départment des Forêts. 2004. *Contribution des insects de la forêt à la sécurité alimentaire: L'exemple des chenilles d'Afrique Centrale.* Fao, Rome, Programme des Produits Forestiers non Ligneux. 112 pp.

Gillon, A. & Knight, E. 1986. *Bourke bush food*. Dubbo, Development and Advisory Publications of N.S.W.

Goddard, C. & Kalotas, A., comp. and ed. 2002. *Punu: Yankunytjatjara plant use.* 2nd ed. Alice Springs, Jukurrpa Books.

Gorham, J.R. 1979. The significance for human health of insects in food. *Annual Review of Entomology*, 24:209-224.

Green, K. 2006. The return migration of Bogong moths, *Agrotis infusa* (Boisduval) (Lepidoptera: Noctuidae), from the Snowy Mountains, New South Wales. *Australian Entomologist*, 33:27-30.

Green, K., Broome, L., Heinze, D. & Johnston, S. 2001. Long distance transport of arsenic by migrating Bogong Moths from agricultural lowlands to mountain ecosystems. *The Victorian Naturalist*, 118: 112-116.

Gullan, P.J. & Cranston, P.S. 2005. *The insects*. 3rd ed. Oxford, Blackwell Publishing.

Hercus, L.A. 1989. Preparing grass witchetty grubs. *Records of the South Australian Museum*, 23: 51-57.

Horwitz, P. & Knott, B. 1995. The distribution and spread of the yabby *Cherax destructor* complex in Australia: speculations, hypotheses and the need for research. *Freshwater Crayfish*, 10: 81-91.

Hunter, D.M. 2004. Advances in the control of locusts (Orthoptera: Acrididae) in eastern Australia: from crop protection to preventive control. *Australian Journal of Entomology*, 43: 293-303.

Isaacs, J. 1987. *Bush food: aboriginal food and herbal medicine*. Sydney, Weldons.

Kimber, R.G. 1984. Resource use and management in central Australia. *Australian Aboriginal Studies*, 1984/2, 12-23.

Kostecka, J. & P[1]czka, G. 2006. Possible use of earthworm *Eisenia fetida* (Sav.) biomass for breeding aquarium fish. *European Journal of Soil Biology*, 42: S231-S233.

Latz, P. 1995. *Bushfires & bushtucker. Aboriginal plant use in Central Australia*. Alice Springs, IAD Press.

Low, T. 1989. *Bush tucker: Australia's wild food harvest*. Sydney, Angus & Robertson.

MacEvilly, C. 2000. Bugs in the system. *Nutrition Bulletin*, 25: 267-268.

Malaisse, F. 2005. Human consumption of Lepidoptera, termites, Orthoptera, and ants in Africa. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 175-230. Enfield, NH, USA, Science Pub.

McKeown, K.C. 1936. *Insect wonders of Australia*. Sydney, Angus & Robertson Ltd.

Menzel, P. & D'Aluisio, F. 1998. *Man eating bugs*. Berkeley, Ten Speed Press.

Meyer-Rochow, V.B. 2005. Traditional food insects and spiders in several ethnic groups of Northeast India, Papua New Guinea, Australia, and New Zealand. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 389-413. Enfield, NH, USA, Science Pub..

Meyer-Rochow, V.B. & Changkija, S. 1997. Uses of insects as human food in Papua New Guinea, Australia, and North-East India: cross cultural considerations and cautious conclusions. *Ecology of Food and Nutrition*, 36: 159-187.

Meyer-Rochow, V.B. 1975. Local taxonomy and terminology for some terrestrial arthropods in five different ethnic groups of Papua New Guinea and Central Australia. *Journal of the Royal Society of Western Australia*, 58: 15-30.

Miers, G. 2004. *Cultivation and sustainable wild harvest of bushfoods by aboriginal communities in Central Australia.* A report for the Rural Industries Research and Development Corporation. RIRDC Web-only Publication No W03/124. RIRDC Project No CLC-1A. 68 pp.

Monteith, G. 2006. Giant wood moth and witchetty grubs. Queensland Museum Fact Sheet. 2 pp.

Morris, B. 2004. *Insects and human life*. Oxford, Berg.

Murphy, B. 2001. *Breeding and growing snails commercially in Australia.* A report for the Rural Industries Research and Development Corporation. RIRDC Project No. ARH-1A. RIRDC Publication No. 00/188.

Naumann, I. 1993. *CSIRO handbook of Australian insect names*. 6th ed. East Melbourne, CSIRO.

O'Brien, M.B. 2007. Freshwater and terrestrial crayfish (Decapoda: Parastacidae) of Victoria: status, conservation, threatening processes and bibliography. *The Victorian Naturalist*, 124(4): 210-229.

O'Dea, K. 1991. Traditional diet and food preferences of Australian aboriginal hunter-gatherers. *Philosophical Transactions: Biological Sciences*, 334: 233-241.

Oyegoke, O.O., Akintola, A.J. & Fasoranti, J.O. 2006. Dietary potentials of the edible larvae of *Cirina forda* (Westwood) as a poultry feed. *African Journal of Biotechnology*, 5 (19): 1799-1802.

Paoletti, M.G., ed. 2005. *Ecological implications of minilivestock*. Enfield, NH, USA, Science Pub.

Paoletti, M.G. & Dreon, A.L. 2005. Minilivestock, environment, sustainability, and local knowledge disappearance. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock*, pp. 1-18. Enfield, NH, USA, Science Pub. pp. 1-18.

Paoletti, M.G., Buscardo, E., Vanderjagt, D.J., Pastuszyn, A., Pizzoferrato, L., Huang, L., Chuang, Y-S., Glew, L.T., Millson, M. & Cerda, H. 2003. Nutrient content of termites (*Syntermes* soldiers) consumed by Makiritare Amerindians of the Alto Orinoco of Venezuela. *Ecology of Food and Nutrition*, 42: 177–191.

Paoletti, M.G. & Dufour, D.L. 2002. Minilivestock. *Encyclopaedia of Pest Management*, 1(1): 487-492.

Paoletti, M.G., Buscardo, E. & Dufour, D.L. 2000. Edible invertebrates among Amazonian Indians: a critical review of disappearing knowledge. *Environment, Development and Sustainability,* 2: 195-225.

Paoletti. M.G. 1995. Biodiversity, traditional landscapes and agroecosystem Management. *Landscape and Urban Planning,* 31: 117-128.

Phelps, D.G. 1997. **Feasibility of a sustainable bush food industry in Western Queensland.** A pre-feasibility study for the Rural Industries Research and Development Corporation. RIRDC Research Paper Series No. 97/11. 112 pp.

Phillips, C. 1993. Longicorn beetles 1. Primary Industries and Resources SA Fact Sheet No. 17. 3 pp.

Phillips, J. & Burkholder, W. 1995. Allergies related to food insect production and Consumption. *The Food Insects Newsletter,* 8(2).

Piper, L. 2000. *Potential for expansion of the freshwater crayfish industryin Australia*. A report for the Rural Industries Research and Development Corporation. RIRDC Publication No. 00/142. 31 pp.

Ramos-Elorduy, J. 2005. Insects: A hopeful food source. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock,* pp. 263-291. Enfield, NH, USA, Science Pub.

Reim, H. 1962. *Die Insektennahrung der Austraslichen Ureinwohner*. Akademie-Verlag, Berlin.

Rich, B.R. 2006. *A feasibility study into the commercialisation of witchetty grubs.* A Report for Rural Research and Development Corporation. RIRDC Publication No 06/109. 58 pp.

Róheim, G. 1933. Women and their lives in Central Australia. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland,* 63: 207-265.

Schulze, L. 1891. The aborigines of the upper and middle Finke River: their habits and customs, with introductory notes on the physical and natural-history features of the country. *Transactions of the Royal Society of South Australia,* 14(2): 210-245.

Short, J.W. 2000. Freshwater crayfish. Queensland Museum Leaflet 0057. 2 pp.

South Australian Museum, n.d. Two giant moths. Information sheet. 2 pp.

Spencer, B. & Gillen, F.J. 1899. *The native tribes of Central Australia*. London, Macmillan and Co. Ltd., London.

Teo, S.S. 2004. Biology of the golden apple snail, *Pomacea canaliculata* (Lamarck, 1822), with emphasis on responses to certain environmental conditions in Sabah, Malaysia, *Molluscan Research,* 24(3): 139-148.

Tindale, N.B. 1966. Insects as food for the Australian Aborigines. *Australian Natural History,* 15: 179-183.

Turner, M.-M. 1994. *Arrernte foods*: *foods from Central Australia.* Alice Springs, Institute for Aboriginal Development Press.

Vantomme, P., Göhler, D. & N'Deckere-Ziangba, F. 2004. Contribution of forest insects to food security and forest conservation: the example of caterpillars in Central Africa. *ODI Wildlife Policy Briefing* No. 3: 1-4.

Yen, A.L. 2005. Insect and other invertebrate foods of Australian Aborigines. *In* M.G. Paoletti, ed. *Ecological implications of minilivestock,* pp. 367-387. Enfield, NH, USA, Science Pub.

Yen, A.L. 2002a. Short-range endemism and Australian Psylloidea (Insecta: Hemiptera) in the genera *Glycaspis* and *Acizzia* (Psyllidae). *Invertebrate Systematics,* 16: 631-636.

Yen, A.L., Gillen, J., Gillespie, R., Vanderwal, R. & the Mutitjulu Community. 1997. A preliminary assessment of Anangu knowledge of Central Australian invertebrates. *Memoirs of the Museum of Victoria,* 56: 631-634.

Yen, A.L. 1993. The role of museums and zoos in influencing public attitudes towards invertebrate conservation. *In* K.J. Gaston, T.R. New & M.J. Samways, eds. *Perspectives on insect conservation*, pp. 213-229. Andover, Hampshire: Intercept Ltd.