

An Overview of Invertebrate Fauna Collections from the Undara Lava Tube System

Arthur Clarke

School of Zoology, University of Tasmania, Private Bag 5, GPO Hobart, Tasmania 7001, Australia
Arthur.Clarke@utas.edu.au

Abstract

In the summer of 1988/1989, the author visited the Undara Lava Tube System, undertaking a study of invertebrate fauna, collecting species from the arid surface and humid subterranean environments. The visit immediately followed the 17th ASF Conference (Tropicon) at Lake Tinaroo, near Cairns, where the significance of the hypogean biodiversity at Undara had been highlighted. The author's subsequent fauna collection at Chillagoe and Undara was undertaken under the auspices of a permit from the Queensland Parks and Wildlife Service.

Serious biological collecting at Undara commenced under the patronage of Brother Nicholas Sullivan from the Explorers Club, New York; he introduced two Hawaiian cave biologists: Fred Stone and Frank Howarth. All three visited and collected from Undara for the first time in 1985, together with local cavers including Doug Irwin. In the following years, they were joined by other expedition biologists, such as the German planthopper specialists Hannelore Hoch and Manfred Asche. Later studies were also carried out on Operation Raleigh by their biologist Michael Godwin and in 1995 and 1997 during the fieldwork conducted by David Slaney working on his PhD dissertation. Unfortunately, there is scant mention of the cave fauna in the September 1999 Management Plan for the Undara Volcanic National Park.

Although a condition of the author's permit required all collected specimens to be lodged in the Queensland Museum (QM), cave fauna from Undara has also been deposited in the Australian Museum (AM) in Sydney and the Australian National Insect Collection (ANIC) in Canberra. Some specimens are being worked on in Germany and USA, where, for example, specimens from QM have been loaned to the Bernice Pauahi Bishop Museum of Honolulu in Hawaii. However, some of the Undara collections have still not been determined for various reasons, including issues related to museum policy and resources, insufficient numbers of a particular species, the immaturity of individual specimens or the absence of an adult male usually required as the holotype for the description of a new species. There is no doubt that the lava tube caves at Undara are amongst the world's most biologically significant and many troglobitic species are recorded. Amongst the best known cavernicolous species from Undara are the troglobitic spiders studied by Mike Gray and Rob Raven, plus the troglobitic reduviid bugs, planthoppers and cockroaches.

Introduction

The Undara Lava Tube system is located about 270 km southwest of Cairns, approximately 18°15' south of the equator in the tropical zone of Australia. Covered by savannah grassland, the Undara cave system forms part of the broad area of vine forest depressions and lava tubes that comprise the McBride Volcanic Province in Far-North Queensland. Invertebrate fauna has been recorded from five areas of number-tagged lava tube caves in the McBride Province: Kinrara (K) Murronga (M), Racecourse (RC), Silent Hill (SH) and Undara (U) (Slaney 2000; Bannink in prep.). Two former Undara caves have been re-allocated: Kenny Cave (formerly U-40, is now part of Silent Hill (SH-1) and U-72 is one of the Racecourse Lava Caves (Bannink in prep.).

The more focussed research of lava cave fauna and ecosystems at Undara did not commence until the mid-1980s. The initial impetus for this hypogean research stemmed from the knowledge that invertebrates had colonised the geologically young lava tubes of Hawaii and were already evolving as tropical zone cave-adapted species (Howarth 1987, 1988; Stone 1988; Sullivan 1988). These tropical zone lava tube species were typically found in association with bat guano deposits or tree roots as depicted in Fig. 1; such habitats commonly occur in the Undara lava tube caves. The search for, and determination of, cave-limited obligates and "non-relictual" troglobites proved to be a major direction for the first significant study in 1985-86, particularly following the discovery of "bad air" or foul air caves such as Bayliss Cave, which subsequently revealed a remarkable diversity of species (Howarth 1987, 1988; Howarth and Stone 1990). In part



Fig. 1. Looking towards rear of Pinwill Cave main chamber, showing the tree roots which provide a habitat, source of food and moisture for tropical cave species such as beetles, bugs, cockroaches, isopods, planthoppers (Figs 3 & 16) and spiders. (photo: Arthur Clarke, 13 August 2010)

coincidental, the second wave of major study and collection at Undara followed immediately after the ASF “Tropicon” Conference held at Lake Tinaroo near Atherton, in late December 1988.

Unfortunately, very few of the lava tube cavernicoles collected from Undara have been taxonomically determined to species level. There are only five groups of described cave-dwelling invertebrates: a troglolithic spider and reduviid bug, three species of cave-limited planthoppers, a troglophilic fly and five cockroaches with two species variants. Two of the cockroach species from Undara are also found in caves at Chillagoe. Among the undescribed species there are three species of a highly troglomorphic cockroach: *Nocticola* sp. (Blattaria: Nocticolidae) known from Bayliss Cave and other lava tube sites (Stone 1988; Howarth & Stone 1990).

The published description of new species is usually accompanied by collection details (collection date, collector’s name, specimen maturity and sex, etc) for all included specimens. Much of this data or information is contained on collection labels that accompany specimens, sitting inside the vials that

form part of a curated museum repository or privately housed collection. This data is particularly important to provide some background to the origin of a specimen, for description of any new species holotype (usually a male) or paratypes and to record detail of the type locality (original or first collection site) where the holotype and possibly some of the paratypes were collected. The following sections provide a chronological history of cave fauna studies at Undara. However, without access to collectors’ original records, museum collections and their databases, this present paper is purely based on the published records of the very few Undara cave invertebrates that have been described to species level by taxonomists such as Mike Gray, Hannelore Hoch, Mallik Malipatil, Rob Raven, Louis Roth and David Slaney.

The earliest collection records for Undara

The first speleological exploration of the Undara lava tubes was primarily undertaken by Brisbane-based members of the University of Queensland Speleological Society, evidenced by early survey maps of The Arch, Barkers, Daves, Ewamin, Picnic and Stephenson’s Caves etc by Dwyer in 1968, plus Hanson and Taylor caves by Ken Grimes in 1977 (Grimes 1977; Godwin 1993). Dwyer was also involved with studies of lava tube dwelling populations of bats at Undara during the early 1970s (Godwin 1993).



Fig. 2. Photomicroscopy image of *Paratemnopteryx stonei* “Race C” variant (Roth 1990) with a blind isopod, both collected from Barkers Cave by Arthur Clarke, 6 January 1989.

One of the first records of invertebrate species from Undara are two spiders from Barkers Cave, recorded by Gray (1973) as *Heteropoda* sp. (then as Family Sparassidae) and *Spermophora* sp. nov. B (Pholcidae: Pholcinae). Related as a “Daddy Long Legs spider” (Gray, unpublished), this pholcid spider was one of the first recorded troglobites in Australia (Gray 1973). Although unclear who observed or collected these spiders, it is probable that most of any early collections were lodged with the Australian Museum in Sydney or ANIC in Canberra. Although Sullivan (1988) reports that Bayliss, Nasty and Pinwill Caves had been biologically studied during three speleo expeditions in the early 1980s, at present, in the absence of known museum, collectors’ or speleo-biology specimen records there is little supporting evidence. The next recorded biological study at Undara was undertaken by Doug Irvin on the weekend of 11-12 July 1984, when he collected three cockroaches from Pinwill Cave and Barkers Cave (Godwin 1993). These specimens were subsequently determined as variants (Race C) of *Paratemnopteryx stonei* (Fig. 2), a species originally described and predominantly known from Royal Arch Cave at Chillagoe (Roth 1990).

The first systematic collections at Undara during the mid to late 1980s

The more serious or intensive cave biology studies at Undara commenced under the patronage of Brother Nicholas Sullivan’s Explorers Club expeditions, run in conjunction with members of the Sydney Speleological Society and Chillagoe Caving Club. During the 1984 and 1985 speleo expeditions to Chillagoe, Sullivan was accompanied by Hawaiian entomologists: Frank Howarth and Fred Stone (Matts 1987; Howarth 1988). In 1985, Howarth and Stone learnt about Anne Atkinson’s studies of the basalt lava tubes at Undara, south of Mt. Garnet (Stone pers. comm.¹; Stone 2010).

Initially guided by Douglas Irvin of the Chillagoe Caving Club in late May 1985 (Stone 2010), Howarth and Stone were also accompanied by Mariam Anderson, Kevin Ridgeway and Tom Robinson (Stone pers. comm.). With enthusiastic support of the Pinwill family who held a grazing lease on Yaramulla Station, Howarth and Stone were able to enter Pinwill Cave (Fig. 1), plus Taylor Cave, Barkers Cave and Bayliss Cave. One of their first recorded collections was made by Frank Howarth in Pinwill Cave on 18 May

1985; he took a ♂ and nymph of the new cockroach subsequently described as *Paratemnopteryx stonei* variant C (Roth 1990) (see Fig. 2). Two days later, Howarth, Stone and Irvin collected another 32 specimens (21 ♂, 4 ♀ and 7 nymphs) and an ootheca (egg case) of this same cockroach, all from Pinwill Cave (Roth 1990).

Together with Dan and Jerry Collins, the team inspected Collins No. 1 Cave and Collins No. 2 Cave on Spring Creek Station (and possibly also Two Ten Tunnel). Over a period of eight days (from 19 to 27 May) Howarth, Irvin and Stone collected a total of 17 adults and three juveniles of a new troglobitic planthopper species (*Undarana collina*) from the neighbouring Collins caves (Hoch & Howarth 1989a). On 21 May, Howarth, Stone and Irvin collected six ♀ of the “C” variant of *P. stonei* from Barkers Cave (Roth 1990). Two days later, in the same cave, they collected four ♂ of the *P. stonei* “C” variant (Roth 1990) and a juvenile schizomid both from near the far reaches of Barkers (Harvey 2001); a possible troglobite, it is probably a new species of the genus *Notozomus* (Schizomida: Hubbardiidae), formerly *F. Schizomida*.



Fig. 3. *Solonaima baylissa* (Hemiptera: Fulgoroidea: Cixiidae) collected from Bayliss Cave by Hannelore Hoch in 1987 and subsequently photographed by Dr Hubert Reimer (Bielefeld, Germany).

21 May 1985 was also the date when the first speleo-biology collections were made in Bayliss Cave. Howarth, Stone and Irvin collected eight cockroaches (5 ♂, 2 ♀ and a nymph) in Bayliss; the specimens were subsequently determined by Roth (1990) to be another variant (“Race B”) of *Paratemnopteryx stonei*. The following day Irvin collected another ♀ of this “B” variant and Stone found a ♂ plus an egg sac (Roth 1990). Also on 22nd, Irvin and Howarth collected the first specimens of a blind planthopper, a ♂ and a juvenile located amongst tree roots 700 m into Bayliss in the deep dark zone. This particular ♂ planthopper

¹ A series of emails from Fred Stone to Arthur Clarke, dated: 10, 26, 28 July 2010, 2, 3, 4, 5 August 2010, with detail of his Undara collection and monitoring trips in part transcribed from his field notebooks and a mix of specific and general comments relating to the regional cave biology.

specimen was later used as the holotype in description of *Solonaima baylissa* (Hoch & Howarth 1989b); see Fig. 3. On 23 May 1985, Howarth, Irvin and Stone collected two more ♂ and a ♀ of the *P. stonei* B variant, plus the first two specimens (a ♀ and nymph) of a blind cockroach (Roth 1990). Initially described by Roth simply as *Paratemnopteryx* sp. 4, this blind species was subsequently re-described as *Neotemnopteryx baylissensis*, following the discovery of four additional specimens in Bayliss and a ♀ in Kenny Cave (Slaney, 2000). During this same three-day period (May 21-23), Howarth, Stone and Irvin collected two ♂ of a cave-adapted reduviid hemipteran bug in Bayliss Cave; both specimens were subsequently used as

abnormally high gas levels – up to 200 times the ambient atmospheric level (Howarth & Stone 1990) – there was the near constant high humidity. During May and June 1985, Howarth and Stone began a systematic collection of cave fauna from selected sites in Bayliss Cave in conjunction with a meteorological study to record CO₂ gas levels, temperature and humidity (Howarth & Stone 1990). The strategically positioned fauna collection sites in Bayliss Cave directly correlated to their series of pre-determined observation points. The recordings were conducted in two phases, firstly from 21 to 23 May 1985, then three weeks later on 14-15 June, when Joan Bresnan joined them (Howarth & Stone 1990; Stone 2010).



Fig. 4. Latero-ventral view of the blind cockroach (*Neotemnopteryx baylissensis*) from Bayliss Cave collected 6 January 1989 by Arthur Clarke.

the holotype ♂ and a paratype ♂ for description of this as *Micropolytoxus cavicolus* (Malipatil & Howarth 1990); see Fig. 5.

Bayliss Cave on Rosella Plains Station became very much the focus of attention, in part due to its unusual lava tube structure with a confined entrance, sloping but undulating floor with a duck-under and wall-like ridge near the lower end. Both these latter-mentioned features appeared to assist the pooling and concentration of trapped carbon dioxide (CO₂) gas probably emanating from the cave fauna such as the roosting bats and resident microbes (James 2010) and perhaps from rotting bat guano and respiring tree roots. James (2010) describes the warm and wet conditions in Bayliss Cave as being perfect for continuous production of microbial CO₂, given the nutrient supply brought into the lava tube by floods and bats. Combined with the

Although there is a record of Irvin collecting the *P. stonei* B variant in Bayliss Cave with Howarth and Stone on 14 June 1985 (Roth 1990), this is probably not correct, based on the recent information given to the writer (Stone 2010) and the lack of corroborating evidence from other sources, e.g., (Hoch & Howarth 1989a; Raven *et al.* 2001). It would appear that Irvin was not at Undara during this period. So it seems more likely that Howarth, Stone and Bresnan collected the *P. stonei* B variant in Bayliss on 14 June, along with the first specimens of a troglomorphic planthopper: *Undarana rosella* (Hoch & Howarth 1989a).

On this same day in the Bayliss Cave, Howarth, Stone and Bresnan collected a possibly troglomorphic ♂ spider: *Australutica* sp. (F. Zodariidae), specimen KS-34401 (Australian Museum records, 2011) previously recorded in Gray (1989) as *Storena*



Fig. 5. With reduced eyes, this setose hemipteran bug from Bayliss Cave, described by Malipatil and Howarth (1990) is considered to be a troglomorphic (cave-adapted) species (Howarth and Stone 1990).

sp., plus the first specimen (♂) of the blind spider *Amauropelma undarra* (Ctenidae) from Bayliss Cave (Raven *et al.* 2001). A ♀ specimen of this eyeless spider is shown in Fig. 7. By way of example of how the classification of species is an ever-changing taxonomic process, when initially examined by Gray (unpublished), this blind spider from Bayliss Cave was listed as a new genus and species of Family Miturgidae: Machadoniinae; then a year or so later Gray (1989) recorded the spider as *Janusia* sp. (F. Ctenidae). On the following day Howarth, Irvin and Bresnan collected two ♀ of this blind ctenid spider in Bayliss (Raven *et al.* 2001) plus an egg sac of the *P. stonei* B variant cockroach (Roth 1990). Finally, on this same day (15 June 1985), three specimens (a ♂, ♀ and egg sac) of the *P. stonei* C variant cockroach were found in Barkers Cave (Roth 1990) along with the only ♀ paratype of the reduviid bug *Micropolytoxus cavicolus* (Malipatil & Howarth 1990) – shown in Fig. 5.

A year later, in May and June 1986, while Stone was in Thailand, Frank Howarth was joined by Manfred Asche, Hannelore Hoch, Doug Irvin, Simon Robson and others studying the fauna of lava tube caves on Spring Creek Station and Rosella Plains Station (Stone 2010; Hoch pers. comm. 2010). A summary of the 1986 expedition to Chillagoe and Undara is provided by Grace Matts who states that “...Howarth had made 27 visits to 18 different [lava] caves, collecting both environmental and biological data. Nearly 1000 specimens of invertebrates are now being processed and identified” and in regard to the Undara cave biology, “...Howarth and Irvin collected between 10 and 15 new troglobitic invertebrates in Long Shot and 210 Cave (lava tubes)...” (Matts 1987). Amongst the



Fig. 6. Head and forelimbs of an undescribed thread-legged bug collected from Wind Tunnel by Arthur Clarke, 7 Jan. 1989 (Hemiptera: Reduviidae: Emesinae). Similar to the troglobitic species in Figs 5 and 14, the red colour around the eyes suggests that the eyes are non-functional. (photo: Arthur Clarke)

recorded troglobites, Matts reports a “blind thread-legged bug and a new *Nocticola* [cockroach]”; among the reported troglophiles are “a blue *Peripatus*... (and)...a population of singing crickets in the deep cave zone” (Matts 1987). In May 1986, five more of the new planthopper *U. rosella* were collected from Bayliss Cave (Hoch & Howarth 1989a). Additional adult and juvenile specimens of *S. baylissa* were collected from Long Shot Cave and Nasty Cave in late May (Hoch & Howarth 1989b). During the last four days of May 1986, Howarth and Irvin collected two ♀ of the blind ctenid spider *Amauropelma undarra* in Bayliss Cave (Raven *et al.* 2001) along with two undetermined species of *Amauropelma* (KS-50695 and KS-50697 in Australian Museum records, 2011). On 31 May they found another ♂ of the reduviid bug *Micropolytoxus cavicolus* (Malipatil & Howarth 1990) (Fig. 5). On 12 June 1986, a ♂ and ♀ of the same *A. undarra* spider were collected from Bayliss Cave by Howarth, Irvin and Robson (Raven *et al.* 2001); all those specimens collected from Bayliss during June 1985 plus May and June 1986 were subsequently used as paratypes for the description of *Amauropelma undarra* (Raven, *et al.* 2001; Australian Museum records, 2011).



Fig. 7. Head of blind ctenid female spider (*Amauropelma undarra*) showing lack of eye spots or lenses. Collected by A. Clarke from Bayliss Cave, 6 January, 1989; it is an unregistered specimen in QM.

Summarising the cave biology expeditions to Chillagoe and Undara, Howarth (1988) recorded that “...about 5000 specimens of cavernicolous arthropods have been collected from the caves in the study area. These represent hundreds of species, many new to science.” Aside from the few voucher specimens deposited at the Queensland Museum, the balance (i.e., vast majority) of the collection was deposited in the Bishop Museum in Honolulu. Some specimens were also distributed to collaborating taxonomists (Howarth 1988). In discussion of results of their Undara studies, Howarth (1987; 1988) states that over 40 troglobitic species are known from two lava tube systems within the McBride Formation and that over one half (24

species) are found in Bayliss Cave and three-quarters of these occur within the delimited stagnant (high CO₂) air zone. A total of 52 species are recorded for Bayliss Cave; the troglobites, defined as “*obligate cave-dwelling species*”, are recorded in an Appendix, together with more troglotic species from other lava tubes (Howarth 1988). This list was subsequently refined in Howarth and Stone (1990, p. 212) recording only the Bayliss Cave species.

In June 1987, the two German planthopper specialists: Manfred Asche and Hannelore Hoch visited Undara for the first time joining Doug Irvin, to collect planthoppers from Bayliss Cave, including four ♂ of *U. rosella* plus 17 and three ♀ of *S. baylissa* (Hoch & Howarth 1989a; 1989b). Together with Irvin in June 1987, Asche and Hoch also collected planthoppers from Barkers Cave, Nasty Cave and Pinwill Cave (Hoch pers. comm. 2011). Their next (second) visit was in January 1989, following the ASF Conference in Queensland, when Asche and Hoch accompanied Fred Stone, Frank Howarth, Douglas Irvin, Anne Atkinson and Terry Matts (Hoch pers. comm. 2011).

Following the 17th ASF Conference (“Tropicon”) held in late December 1988 at Lake Tinaroo, North Qld, when the Undara lava tubes and their biology were particularly high-lighted (Atkinson 1988; Hoch & Asche 1988; Howarth 1988; Stone 1988), the year 1989 proved to be the commencement of another significant period for cave fauna collections at Undara. During the latter part of the first week of January 1989, together with Mick Williams (Fig. 20) from the Snowy Mountains Speleological Society, the writer commenced a collection of species from Undara at the behest of Anne Atkinson and members of the Chillagoe Caving Club, under permit from the Queensland Parks & Wildlife Service.

Barkers Cave and Bayliss Cave were inspected, sampled and photographed by Clarke and Williams on 6 January 1989. The collected specimens from Barkers Cave include a number of adult and juvenile cockroaches, presumably the *Paratemnopteryx stonei* (Race C) variant, often underneath clusters of bats (see Fig. 10) and found in abundant numbers on the guano covered lava tube walls (Fig. 11); a hemipteran reduviid bug: *Coranus* sp., undetermined ants (Formicidae: Dolichoderinae) and weevil beetles



Fig. 8. Blind cheliferid pseudoscorpion (**Protochelifer**, near *P. cavernarum*) with long but powerful pedipalps, collected from Wind Tunnel by Arthur Clarke on 7 January 1989; still (unregistered) in QM.

(Coleoptera: Curculionidae), some *Omorgus* sp. “hide” beetles (Fig. 12) belonging to a cave-like sounding family (Superfamily Scarabaeoidea: F. Trogidae) and several large and very setose (hairy) normal-eyed huntsman spiders: *Heteropoda* sp. (F. Sparassidae, formerly classified as Heteropodidae). The Bayliss specimens included several prominently troglitic species such as the blind cockroach (*Neotemnopteryx baylissensis*) (Fig. 4), a depigmented centipede with reduced eyes, several blind isopods, an eyeless silverfish (Thysanura), the cave-adapted hemipteran bug *Micropolytoxus cavicolus* (Reduviidae) with non-functional eyes, a tiny blind mite, the blind cave spider *Amauropelma undarra* (Ctenidae) and several specimens of the seemingly cave-adapted long-legged spiders assigned as undetermined species of Pholcidae. The following day we were in Wind Tunnel (U-42), where a blind pseudoscorpion was discovered; the collected specimen of *Protochelifer* sp., near *P. cavernarum* (Cheliferidae) is shown in Fig. 8. Also seen grazing on a small mound of bat guano were some cockroaches and several undetermined beetles (carabids and staphylinids), plus *Pterohelaeus* sp. (Tenebrionidae), *Omorgus* sp. (Trogidae) and an undetermined dermestid beetle. Some depigmented ants were tentatively determined as species of *Paratrechina* (Formicidae: Formicinae) and the hemipteran bug (shown in Fig. 6) is likely to be a new unknown species of the reduviid sub-family Emesiinae.

Barkers Cave was revisited during the evening on 7 January to photograph the emergence of bats (Fig. 9)



Fig. 9. Emergence of bats from Barkers Cave, just after dusk on the evening of 7 January 1989. This photograph by Arthur Clarke was used as the front dust cover photo of Atkinson & Atkinson (1995).



Fig. 10. Huddling together for warmth, with minimal hair covering and still unopened eyes, these juvenile bats were photographed by Arthur Clarke on 7 Jan. 1989, at the edge of a maternity site on the wall above the lake in Barkers Cave; a former lake level is just discernible near the bat's left ear.

and the pythons at the cave entrance and to sample epigeal (surface) species found in the forest litter near (just outside/inside) the cave entrance. The collected entrance species include several beetles: *Australobolbus* sp. (Scarabaeoidea: Bolboceratidae), two tenebrionids: *Pterohelaeus* and *Ommatophorus* sp. and an undetermined scarab beetle (Scarabaeoidea: Scarabaeidae: Melonthinae); a cicada *Illyria burkei* (Hemiptera: Cicadidae); a hemipteran bug *Diplonychus* (Hemiptera: Belostomatidae), a termite: *Mastotermes darwiniensi* (Isoptera: Mastotermitidae); *Polistes* sp. wasps (Vespidae); *Anochetus* sp. ants (Ponicerinae); and undetermined tabanid horse flies. Collected species from within Barkers Cave included cockroaches, isopods, millipedes, dolichoderid ants and a chrysomelid beetle (Chrysomelidae: Galerucinae). The few species collected from Pinwill Cave on 8 January include some undetermined but spinose and setose cave-adapted spiders, pholcid spiders, guanophile mites, an unknown reduviid bug, tineid moths, histereid beetles, an undetermined Psocoptera and a range of undetermined ants.

Following the departure of Clarke and Williams, another group of ASF Conference attendees (all cave biologists) arrived at Undara to accompany Fred Stone and Frank Howarth, including Irvin, Hoch and Asche, plus Stefan Eberhard from Tasmania. Present from 10 to 12 January 1989, the group inspected and sampled a number of lava tubes including Barkers

Cave, Bayliss Cave, Darcy Cave and Nasty Cave (Stone 2010). Howarth is recorded as collector for a juvenile ♀ spider: *Forsterina* sp. (Desidae) from Darcy Cave on January 10th (KS-22428 in Australian Museum records, 2011). Following departure of the most cave biology visitors, Howarth collected a new spider from Michaels Cave on 16th January 1989; this became a paratype in Davies (1994) for her description of *Heteropoda alta* (now Sparassidae) (KS-22430 in Australian Museum records, 2011). On January 20th Howarth collected a juvenile of *Heteropoda* from Darcy Cave and another female spider: *Selenocosima crassipes* (Theraphosidae) from Long Shot Cave (both registered as KS-22429 and KS-22427 respectively, in Australian Museum records, 2011).

Later that same year, from September to November 1989, the London-based Operation Raleigh venturers came to Undara and commenced a determined programme of cave exploration, surveying and mapping. Lead by Brian Furniss, the activities of the Raleigh group were supervised by Mick Godwin from the Qld. National Parks & Wildlife Service; he also performed most of the cave biology work. Godwin was the only person actively engaged with invertebrate collections during the time of Operation Raleigh when over 30 new lava tubes were discovered, in addition to the mapping of over 30 known lava tubes, making a total of about 65 lava tubes (Stone 2010). On 13 October 1989, Mick Godwin collected the very first specimens of *Neotemnopteryx undarensis* (Blattaria: Blattellidae) from Undara in Hot Hole (U-51), then ten days later (24 October), Lana Little collected the first specimens of *N. undarensis* from U-52 (Wishing Well Cave) (Slaney 2000). During the time of Operation Raleigh and over the next four years, Mick Godwin compiled all the relevant data for Undara, culminating in a large 360 page report including Appendix listing the known and recorded vertebrates and invertebrates from caves and surface sites (Godwin 1993).

Towards the end of December 1989, Fred Stone was at Undara again in the company of Tanya Stone, Troy Pinwill, Don Pinwill and others (including Lauren, Sonia and Michael) (Stone 2010). Amongst the many caves visited and sampled were: Archways, Picnic Cave, Road Cave, Bayliss Cave, Kenny Cave, Pinwill Cave, (Don Pinwill's) Secret Caves, where a blind cockroach was discovered in U-67 (CCC map no. 409 in Godwin 1993), Wind Tunnel, Travis Cave, Johnson Cave, Hanson Cave, Taylor Cave, Michaels Cave, Grahams Cave, Barkers Cave and Nasty Cave.

Further collections in the 1990s

The January 1990 Explorers Club expedition was once again lead by Brother Nicholas Sullivan and partially sponsored by Dick Smith and the Australian Geographic Society (Dyce & Wellings 1991). An unusual discovery was the first record of phlebotomine sandflies at Undara with 40 specimens (20 ♂ and 20 ♀) of *Idiophlebotomus wellingsae* (Psychodidae: Phlebotominae) collected in Pinwill Cave, with the aid of a light trap (Dyce & Wellings 1991). Also known from three caves at Chillagoe (Haunted Cave No. 2, Donna Cave and Tea Tree Cave), these sandflies are generally found in association with bat guano.

On 10 April 1990, Mick Godwin collected *Neotemnopteryx baylissensis* from Kenny Cave and then on 14 April he located additional specimens (a ♀ and two juveniles) of *Neotemnopteryx undarensis* in Wishing Well Cave (Slaney 2000). On 19 November 1993, Philip Weinstein collected a single ♀ and two oothecae (egg cases) of *Neotemnopteryx baylissensis* from Bayliss Cave. In mid-September 1994, Godwin and Barnes collected *Neotemnopteryx undarensis* from Stephens Cave (U-16) (Slaney 2000). On 3 February 1995, a blind male cockroach was collected from Bayliss Cave by David Blair; this specimen ultimately became the holotype for description of *Neotemnopteryx baylissensis* (see Fig. 4).



Fig. 11. Scavenging *Paratemnopteryx stonei* (Race C variant) cockroaches on the bat guano strewn walls of Barkers Cave. (photo: Arthur Clarke 7 January 1989)

From April 1994 to July 1995, a large collection of *Paratemnopteryx stonei* cockroaches was amassed by David Slaney and Philip Weinstein, removed from caves at Undara and Chillagoe (Slaney & Weinstein 1997). Slaney and Weinstein were assisted by David Blair, Doug Irvin, Fred Stone, Erich Volschenk, Deborah Ward and others (Stone 2010). A total of 164 adult specimens were selected from a much larger

collection of *P. stonei* cockroaches, taken from seven caves, with over half of these (89 adults) taken from two caves at Undara: Barkers Cave (16 ♂ and 25 ♀) and Bayliss Cave (21 ♂ and 27 ♀) (Slaney & Weinstein 1997). The adults were subsequently examined and dissected by Slaney and Weinstein to ascertain the geographical variation in different troglomorphic adaptations between cave populations, e.g., eye width, eye length and tarsus (foot) length. In late July 1995, Messrs. Irvin, Slaney and Stone, plus Debbie Ward collected other cave-dwelling invertebrates from Nasty Cave and Pinwill Cave (Stone 2010).



Fig. 12. Marauding scarab dung beetles (*Omorgus* sp.) near bat carcass and dung on dirt floor of Barkers Cave; note the dried skeletal remains of bats. (photo: Arthur Clarke, 7 January 1989)

During 1995-96 five additional *Paratemnopteryx* cockroaches were collected from caves (Slaney & Blair 2000) and together with the previously sampled specimens were subjected to Scanning Electron Microscope examination to conduct further morphometric analyses. In this second round of studies, the respective populations of *P. howarthi* and *P. stonei* from caves at Undara and Chillagoe were examined to determine the variation and differences in mouthpart structures and antennae. The cockroach collections were primarily used to compare the differences in *P. stonei* morphology between Bayliss and Barkers and the morphological variations between the Undara and Chillagoe populations of *P. howarthi* (Bland *et al.* 1998a; 1998b). Several variations in the cave dwelling populations of *P. stonei* had previously been noted by Louis Roth who defined the Bayliss Cave population as “Race B” and Barkers Cave as “Race C” (Roth 1990). On 5 February 1996, David Slaney and Erich Volschenk collected ♂ and ♀ cockroaches and their oothecae (egg cases) from Wishing Well Cave (U-52), including the specimen which became the ♂ holotype for the description of *Neotemnopteryx undarensis* (Slaney 2000). On 8 February 1996, a ♂ spider collected from Bayliss Cave by Erich Volschenk and David Slaney subsequently became the holotype for description of *Amauropelma undarra* Raven and Gray

(Ctenidae) (Raven *et al.* 2001).

In the following year (1997), Stone was at Undara once more, this time for a shorter period from 22 to 24 March (Stone pers. comm). Accompanied by Dave Rowe and Merv Shaw, they collected species from Bayliss Cave, Barkers Cave, Nasty Cave and Pinwill Cave (see Fig. 12). Collection records indicate that on 23 March 1997, Stone took another ♀ and two juveniles of *Neotemnopteryx baylissensis* from Bayliss Cave (Slaney 2000). Three months later, Stone was back again, and on 17-18 June, he was accompanied by Irvin inspecting cave fauna habitats and collecting troglobitic “nockies” (*Nocticola* cockroaches) in Long Shot Cave on Spring Creek Station, in preparation for a proposed description of this new nocticolid species.

In the most recent times, surveys of the Undara lava tube fauna have been conducted in conjunction with vertebrate studies under the auspices of the Einasleigh Fauna Survey (Mick Godwin pers. comm. 11 Aug. 2010). This fauna survey has been run sporadically by several people, the most recent being Keith McDonald from the Environment Protection Agency in Atherton. Most of the Undara invertebrate specimens have been housed with the Mick Godwin Collection (MGC) at QPWS in Cairns, whereas the vertebrate specimens were generally sent to the Queensland Museum in the first instance or QPWS.

A summary of the known troglobitic species

Although the exact number of cave-dwelling species at Undara will probably never be known, present estimates indicate that among the species showing some degree of troglomorphic (cave adaptation) characters, there are a number of troglobitic obligates (Howarth 1987), most of which are locally endemic. There is an observed correlation between the evolution of troglomorphic characters or troglobitic diversity and the harsh or tenuous living habitats of subterranean bio-space (Clarke 2006). A correlation of troglobitic diversity due to “bad air” (high CO₂ levels) and constant high humidity in Bayliss Cave was noted during the studies by Frank Howarth and Fred Stone in 1985 and 1986 (Howarth 1987; 1988; Howarth and Stone 1990).

Together with recent updates from Stone, plus the work of Mick Godwin and others e.g., Pearson (2010), the report by Howarth and Stone (1990) has been used by the Queensland Parks and Wildlife Service to produce a management plan for the Undara Volcanic National Park (QPWS 2000). Although relatively scant in cave fauna detail, the management plan includes the following statement: “...Within the lava tubes are found distinct communities of troglobitic



Fig. 13. Photomicroscopy image of the translucent body of a blind cockroach collected from Bayliss Cave on 6 January 1989. Although probably an immature specimen of *Paratemnopteryx* or *Neotemnopteryx*, this juvenile might be *Nocticola*, species of which are referred to as “nockies” by Fred Stone.

species, many of which are undescribed and/or endemic to these systems. This includes isopods of the Superfamily Oniscoidea, spiders of Family Pholcidae (*Spermophora* sp. nov. B), Family Zodariidae, Family Nesticidae and a sightless hunting spider of unknown affinity, two species of Polydesmida, centipedes (*Chilopoda: Scutigleromorpha*), silverfish (*Thysanura*), cockroaches (Family Blattellidae), two species of assassin bugs (Family Reduviidae) and a number of beetles (Family Staphylinidae) (Gray 1989; Howarth 1988)...” (QPWS, 2000).

Amongst the many undescribed troglobites from Undara there are the numerous centipedes (e.g., Fig. 13), millipedes and spiders (Figs. 19, 20), plus pseudoscorpions (Fig. 8), schizomids, isopods (Fig. 2), springtails, curculionid weevils, thysanura (silverfish or bristletails) and cockroaches (see below). There are a number of other likely troglobites including carabid and staphylinid beetles, thread-legged emesine reduviids and dolichoderine or formicine ants (Formicidae). The known described species fall into four groups: cockroaches, reduviid bugs, spiders and planthoppers.



Fig. 14. Hemipteran reduviid bug, in Pinwill Cave (photo: Arthur Clarke, 13 August 2010)



Fig. 15. Photomicroscopy image taken by Arthur Clarke, showing head and forelimbs of an undescribed blind centipede collected from Bayliss Cave on 6 January 1989. The sharply pointed, highly sclerotinised and modified spines, suggest this is likely to be another troglolitic species.

(a) Cockroaches (Dictyoptera: Blattaria: Blattellidae & Nocticolidae)

The described troglolitic species are the blind *Neotemnopteryx baylissensis* (Blattellidae) from Bayliss Cave and Kenny Cave (Slaney 2000) plus *Neotemnopteryx undarensis* (Blattellidae) from Stephens Cave, Hot Hole and Wishing Well Cave (Slaney 2000). *N. baylissensis* was formerly described as *Paratemnopteryx* sp. 4 in Roth (1990). Three troglolitic blattellid species are known: *Paratemnopteryx stonei* (Race B) variant from Bayliss Cave (Roth 1990; Slaney & Blair 2000), *Paratemnopteryx stonei* (Race C) variant in Barkers Cave and Pinwill Cave (Roth 1990) and U-42(?) and *Paratemnopteryx howarthi* from Nasty Cave (Bland *et al.* 1998a; 1998b). There is at least one, and possibly more, highly troglolitic nocticolid cockroach species. Likely to be species of *Nocticola* (Nocticolidae) they are known from Bayliss Cave (Fig. 15), Long Shot Cave, Pinwill Cave (Fig. 16) and Upper Secret Cave (Stone 1988; Howarth & Stone 1990; Godwin 1993; Clarke 2010).

(b) Reduviid bugs (Hemiptera: Heteroptera: Reduviidae: Saicinae)

Micropolytoxus cavicolus (Reduviidae) from Bayliss Cave (Malipatil & Howarth 1990).

(c) Spiders (Araneae: Ctenidae, Heteropodidae, Nesticidae, Pholcidae & Zodariidae)

First recorded as *Janusia* sp. (Ctenidae) by Gray (1989), this blind troglolitic ctenid, only known from Bayliss Cave, is now described as *Amauropelma undarra* (Ctenidae) from Bayliss Cave (Raven & Gray

2001) (see Fig. 7). Additional troglobitic, but still undescribed, species from Bayliss include: *Nesticella* sp. 1 (Nesticidae) and *Australutica* sp. (Zodariidae) (Gray unpublished; 1989; Howarth and Stone 1990; Bannink in prep; Australian Museum records 2011). Possibly adapted, but nevertheless trogliphilic, spiders include *Heteropoda* sp. (Sparassidae) from Barkers Cave (U-34) and Darcy Cave (U-31), *Heteropoda* alta (Sparassidae) from Michaels Cave, *Nesticella* sp. 2 (Nesticidae) and *Spermophora* sp. nov. B (Pholcidae) (Gray, unpublished; 1973; 1989; Australian Museum records, 2011).



Figure 16.: Photograph of the troglobitic planthopper *Undarana collina* from Collins Cave; from a transparency taken March 1997 by Paul Zborowski; image scanned 20 January 2011.

(d) Planthoppers (Hemiptera: Fulgoroidea: Cixiidae: Cixiinae)

Two troglobitic obligates: *Undarana collina* (Hemiptera: Fulgoroidea: Cixiidae: Cixiinae: Brixini) from Collins No. 1 and Collins No. 2 Cave (Fig. 16) and *Solonaima baylissa* (Hemiptera: Fulgoroidea: Cixiidae: Cixiinae: Brixini) from Bayliss Cave (Fig. 3), Long Shot Cave and Nasty Cave (Hoch & Howarth 1989a; 1989b). A trogliphilic cixiid: *Undarana rosella* is recorded from Bayliss Cave (Hoch & Howarth 1989a) and Pinwill Cave (Hoch & Howarth 1989a).

Surface collections in and around the lava tube entrances

Aside from the surface collections by Godwin and Clarke and any recent endeavours under the auspices of the Einasleigh Fauna Survey, the Queensland Naturalists Club ran a series of investigations searching for scarab dung beetles at Undara in the summer of 2002-2003. The two caves selected for pitfall trapping were The Arch and Wind Tunnel (Monteith 2003). A total of 33 species of this superfamily Scarabaeoidea

were recorded, principally *Amphistomus squalidus*, five different species of the genus *Onthophagus* (including a new species of the pexatus-group), plus two species of genus *Coptodactyla*, though *C. gabricollis* appears more restricted to the enclaves of granite (Monteith 2003).

Locating the collected Undara specimens and getting determinations

As a general rule, collected biological specimens are deposited with an institution or organisation in the region, State or Country where collected. There are exceptions, especially, for example, when there is no local or regional expertise or means to have biological specimens registered (or accessioned) in a recognised institution, then adequately curated in appropriately sealed or stoppered glass containers with the correct preserving liquid and accompanying collection labels. If being deposited in an institution or museum, it is assumed that the lodged specimens will acquire some degree of taxonomic determination at least to Family level or genus and if new species, they will eventually be described. In some instances, where for example the collectors are taxonomists or invertebrate specialists based in a recognised museum or institution, such as Ashe, Hoch, Howarth, Malipatil, Slaney and Stone, the bulk of their collection can be taken interstate or overseas, providing that at least one of each collected species is deposited as a voucher specimen in a central location, e.g., a capital city museum in the State or Country of collection. Alternately, specimens can be accessioned to a museum and then sent off on "loan" to taxonomists or specialists.

Under the auspices of the Queensland Parks and Wildlife Service (QPWS) permit requirements, Arthur Clarke's collected Undara specimens were lodged with the Queensland Museum and have remained there ever since, unregistered and in the different sections, e.g., Entomology, Arachnids, Molluscs, etc. Following some updated determinations from their retired entomologist, Geoff Monteith, the insect component of Clarke's collection has been forwarded to the Tasmanian Museum in Hobart, where Clarke is currently engaged as a volunteer. The rest of Clarke's collection, including several undescribed troglobites, remains with the Queensland Museum, still not registered and without determinations. Aside from issues related to specimen damage during collection or inadequate curating, specimens from collections may not be determined for various reasons, including issues related to museum policy and resources, insufficient numbers of a particular species, the immaturity of individual specimens or the absence of an adult ♂ (usually required as the holotype for the description of a new species).



Fig. 17. Photomicroscopy image depicting the head of a new undescribed spider, possibly ?*Nesticella* sp. from Pinwill Cave. The eyes (without pigment) would appear to be non-functional and with the dense matt of sensory hairs (looking like a paint brush) at the front of its head and the antenna-like spines, it is likely to be a troglolithic species. (photo: Arthur Clarke)

Major repositories for the Undara invertebrate fauna collections

Most of the invertebrate species taken from Undara have been lodged in museums within Australia, e.g., Australian Museum in Sydney or the Queensland Museum (QM) in Brisbane; the latter includes the QM material on loan to Bernice P. Bishop Museum in Honolulu and to H. Hoch, Museum für Naturkunde (Museum of Natural History), at Humboldt University in Berlin. Listed alphabetically by acronym, the following are the major known repositories for the cave and surface specimens from Undara:

ACC (Arthur Clarke collection): insects held at Tasmanian Museum & Art Gallery, Hobart with the arachnids, millipedes, centipedes, and snails, etc still held at Queensland Museum;

AHC (Asche and Hoch Collection): Museum für Naturkunde (Museum of Natural History) at Humboldt University in Berlin, Germany, e.g., planthoppers, on loan from QM;

ANIC (Australian National Insect Collection), CSIRO, Canberra, ACT: e.g. *Neotemnopteryx* cockroaches. Despite the name, this institution is also home to numerous non-insect specimens;

AUSMUS (Australian Museum) Sydney, NSW, e.g., cave spiders;

BDUH (Biology Department, University of Hawai'i) in Hilo, Hawaii, USA, e.g., cockroaches, on loan from QM;

BMNH (British Museum of Natural History), London,

e.g., *Solonaima* planthoppers;

BPBM (Bernice Pauahi Bishop Museum) Entomology section, Honolulu, Hawai'i, USA, e.g., the Bayliss Cave collection of troglolithes and other species, on loan from QM;

FSC (Fred Stone collection), Kurtistown, near Hilo, Hawai'i, USA, e.g., *Nocticola* cockroaches;

MCZH (Museum of Comparative Zoology Harvard University), Cambridge, Massachusetts, USA, e.g., *Paratemnopteryx* cockroaches (Roth 1990);

MGC (Mick Godwin collection) at the Dept. of Environment & Heritage, Cairns, Qld: e.g. *Neotemnopteryx* cockroaches;

NTMAG (Northern Territory Museum & Art Gallery) in Darwin, e.g., *Micropolytoxus* reduviid bugs;

QM (Queensland Museum) in Brisbane, e.g., spiders, insects, gastropods, centipedes, etc.



Fig. 18. Possibly a blattellid (and possibly a new species of *Neotemnopteryx*), this fast moving and apparently blind and quite setose cockroach carrying its egg sacs and scurrying across the floor of Pinwill Cave, was photographed by Arthur Clarke on 13 August 2010.

Where to from here? Expanding our Undara collection knowledge

In order to expand the knowledge of the collected Undara cave fauna, there is a need to access museum collections, their card indexes or electronic databases to check their lists of registrations or accessions, or in the case of unregistered material, to inspect their lodgements.

Following are some questions that could be asked of museums, their collection managers or specialist curators:

Where are the specimens now (institutional lodgement; private collection)?

Do you have any knowledge of, or record of,

invertebrate fauna specimens from Undara in your collections?

Is there a record of when the specimens from Undara were collected (year/ month/ day, etc) and when they were lodged in your institution?

Is there any indication whether these were collections undertaken by invertebrate specialists or cave biologists, or were they just incidental collections by cavers or visitors at the time of lava tube exploration or surface transects?

Who were the collectors (name of collector/s or taxonomist/s)?

How was the collection performed, i.e. under what auspices (expedition; private visit; specific research project; post-grad degree project)?



Fig. 19. Long-legged spider, possibly a pholcid, manipulating egg sac bundle along its silken web strands amidst tree roots in Pinwill Cave. (photo: Arthur Clarke, 13 August 2010)

Do your records show what sort of species were collected and from what habitats (surface epigeal terrestrial; subterranean hypogean terrestrial/ aquatic)?

Are we able to ascertain the precise whereabouts or collection sites for these specimens at Undara (surface site locations; named or un-named caves or lava tubes)?

What types of species were collected?

When were the specimens determined and/ or described (and who is the species authority)?

Addendum: Recorded invertebrates from the Undara region

Four major lists of invertebrate species from Undara are known to this writer. Firstly, the published list of fauna from Barkers, Bayliss, Collins, Long Shot, Nasty, Road, Taylor and Two-Ten caves, recorded as Appendix 1 in Howarth (1988) and then the Bayliss Cave collection alone in Howarth and Stone (1990: p. 212).

In this latter paper, the authors list 46 species collected at specific sites on 14-15 June 1985. The species are listed according to their subterranean ecological status as troglonexes (6 species), trogliphiles (16), partially troglomorphic troglobites (7) and strongly troglomorphic troglobites (17) (Howarth and Stone 1990). Almost half of these have been determined to genus level with six to species level. There is a minor error in the original 1990 list where the two partially troglomorphic terrestrial isopods, correctly listed in Howarth (1988) as Oniscoidea, are listed in Howarth and Stone as undetermined species 1 and 2 of "Isopoda: Oniscomorpha". In fact, the term "Oniscomorpha" refers to a different group of animals known as pill millipedes which have a close resemblance to certain isopods, particularly the so-called pill bugs of the family Armadillidiidae. It is possible that there was some confusion in the compilation of this 1990 list, because some of these pill bug isopods are recorded from caves at Chillagoe (Howarth 1988).

Howarth (1988) also lists a number of invertebrates from additional lava tube sites at Undara; most of these are considered to be troglobitic (Tb) species:

Aquatic Amphipoda: Road Cave (Tb);

Arachnida: Araneae: Pholcidae: *Spermophora* sp. B from Collins Cave (Tb);

Arachnida: Araneae: Zodariidae: Nasty Cave;

Arachnida: Phalangida "Daddy Long Legs" (i.e., opiliones harvestmen): Long Shot Cave (Tb?);

Arachnida: Schizomida: Schizomidae (schizomids): Barkers Cave (Tb?);

Chilopoda: scutigermorpha (centipede): Barkers and Nasty caves (possibly Tb?);

Coleoptera: Curculionidae: Rhytirhininae (blind weevil): Taylor Cave (Tb);

Dictyoptera: Blattaria: Nocticolidae: *Nocticola* cockroaches: Long Shot and Nasty caves (Tb);

Diplopoda: Cambalida: (millipede): Nasty Cave (Tb);

Hemiptera: Reduviidae: Emesinae (thread-legged bugs): Long Shot and Two-Ten caves (Tb);

Homoptera: (now referred to as "Auchenorrhyncha") Cixiidae: Cixiinae (planthoppers): Collins, Long Shot, Nasty and Two-Ten caves (cave-adapted & Tb?);

Isopoda: Oniscoidea (terrestrial isopods): unspecified Undara lava tubes (cave-adapted?);

Onychophora (peripatus): Long Shot and Two-Ten caves (possibly Tb?).

Unfortunately, the higher order taxonomy for some species in Howarth (1988) and Howarth and Stone (1990) is not correct, possibly because their taxonomy and distribution was not accurately known at the

time. For example, species of Family Schizomidae are only recorded in Mexico and North America and the reference to “cambaliform millipedes” (Howarth 1988) or the blind “Cambalida” millipede (Howarth and Stone 1990) is not applicable here in Australia. It should be noted that while “*Cambalida*” is the genus name for a spider (Family Corinnidae) known only from West Africa, there is a “Cambalida” group of millipedes that include cave dwelling and cave adapted species, but these are predominantly recorded from North America and Hawai’i. To confuse the issue further, there is at least one Australian species belonging to the millipede family Cambalidae (Order Spirostreptida) recorded from near Scone in NSW (Mesibov 2002). Although Godwin possibly intended to include these millipedes in a similar manner, perhaps by Order name, being listed as “*Cambalida* sp.” (Godwin 1993) this could be misread as a genus name.

The third list of invertebrate species was compiled by Mick Godwin, forming part (pp. 350-354) of Appendix 11 (“Fauna”) of his 1993 compilation. Recording his species according to the relevant “MGC” (Mick Godwin Collection) number, this list also includes a number of epigeal (surface) species such as gastropod snails collected from “*under bark of ironbark trees*” (Godwin 1993). Although about 70 different cave-dwelling species are recorded, including most of those recorded by Howarth and Stone (1990), the lack of taxonomic resolution as a “black hole” in biospeleology is noted by Godwin (1993) with many species simply listed, for example as “Isopod sp. 1” to “sp. 6”.

A list of the species collected by the author in January 1989 is included as Appendix.

All photographs in this paper are © Arthur Clarke 2010, except Figure 3 © Hubert Reimer, Germany and Figure 16 © Paul Zborowski, Queensland.

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APPENDIX:
**Invertebrate species collected in January 1989 by Arthur Clarke from
selected caves and surface sites near cave entrances in the Undara lava tube system.**

Number	Collection site	Date	Higher order classification	Genus species (if known)	home
189/110	Barkers Cave (U-34)	06/Jan/1989	Arachnida: Araneae: Sparassidae (?)	<i>Heteropoda ?jugulans, possibly Tp</i>	QM
189/111	Barkers Cave (U-34)	06/Jan/1989	Arachnida: Araneae: Sparassidae (?)	<i>Heteropoda ?jugulans, possibly Tp</i>	QM
189/112	Barkers Cave (U-34)	06/Jan/1989	Arachnida: Araneae: Sparassidae (?)	<i>Heteropoda ?jugulans, possibly Tp</i>	QM
189/113	Barkers Cave (U-34)	06/Jan/1989	Arachnida: Araneae: Pholcidae (?)	undet. pholcid spider	QM
189/114	Barkers Cave (U-34)	06/Jan/1989	Blattaria: Blattellidae: Blattellinae	<i>Paratemnopteryx stonei (Race C)</i>	TMAG
189/115	Barkers Cave (U-34)	06/Jan/1989	Blattaria: Blattellidae: Blattellinae	<i>Paratemnopteryx stonei (Race C)</i>	TMAG
189/116	Barkers Cave (U-34)	06/Jan/1989	Blattaria: Blattellidae	undetermined cockroach	TMAG
189/117	Barkers Cave (U-34)	06/Jan/1989	Crustacea: Isopoda: Oniscoidea	undet. blind oniscoid isopod	TMAG
189/118	Barkers Cave (U-34)	06/Jan/1989	Crustacea: Isopoda: Oniscoidea	undet. oniscoid isopod (tiny eyes)	TMAG
189/119	Barkers Cave (U-34)	06/Jan/1989	Hemiptera: Reduviidae: Harpactorinae	<i>Coranus sp.</i>	TMAG
189/120	Barkers Cave (U-34)	06/Jan/1989	Hymenoptera	undetermined ant	QM
189/121	Barkers Cave (U-34)	06/Jan/1989	Hymenoptera: Formicidae: Dolichoderinae	undetermined ant	TMAG
189/122	Barkers Cave (U-34)	06/Jan/1989	Hymenoptera: Formicidae: Dolichoderinae	undetermined ant	TMAG
189/123	Barkers Cave (U-34)	06/Jan/1989	Coleoptera: Curculionidae	undetermined weevil	TMAG
189/124	Barkers Cave (U-34)	06/Jan/1989	Coleoptera: Trogidae	<i>Omorgus sp.</i>	TMAG
189/125	Bayliss Cave (U-30)	06/Jan/1989	Blattaria: Blattellidae: Blattellinae	<i>Neotemnopteryx baylissensis</i>	TMAG
189/126	Bayliss Cave (U-30)	06/Jan/1989	Blattaria: Blattellidae: Blattellinae	<i>Neotemnopteryx baylissensis</i>	QM
189/127	Bayliss Cave (U-30)	06/Jan/1989	Chilopoda: Scutigermorpha (?)	undetermined centipede	QM
189/128	Bayliss Cave (U-30)	06/Jan/1989	Chilopoda: Scutigermorpha (?)	undetermined centipede	QM
189/129	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Ctenidae	<i>Amauropelma undarra (♀)</i>	QM- 88939
189/130	Bayliss Cave (U-30)	06/Jan/1989	Crustacea: Isopoda: Oniscoidea	undet. blind oniscoid isopod	TMAG
189/131	Bayliss Cave (U-30)	06/Jan/1989	Thysanura: Nicolectidae (?)	?Nicoletia sp. (blind)	TMAG
189/132A	Bayliss Cave (U-30)	06/Jan/1989	Lepidoptera: Geometridae	undetermined larva	TMAG
189/132B	Bayliss Cave (U-30)	06/Jan/1989	Diplopoda: Polydesmidae	undet. polydesmid millipedes	TMAG
189/133	Bayliss Cave (U-30)	06/Jan/1989	Hemiptera: Reduviidae: Saicinae	<i>Micropolytoxus cavicolus</i>	TMAG
189/134	Bayliss Cave (U-30)	06/Jan/1989	Hymenoptera: Formicidae: Ponicerinae	<i>Amblyopone sp</i>	TMAG
189/135	Bayliss Cave (U-30)	06/Jan/1989	Diplopoda: unknown	undetermined millipede	QM
189/136	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Acarina	undetermined blind mite	QM
189/137	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Araneae: Nesticidae (?)	?Nesticella sp.	QM
189/138	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Araneae: Ctenidae	<i>Amauropelma undarra (juv. ♀)</i>	QM- 88942
189/139	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Araneae: Pholcidae	undet. pholcid spider	QM
189/140	Bayliss Cave (U-30)	06/Jan/1989	Arachnida: Araneae: Pholcidae	undet. pholcid spider	QM
189/142	Wind Tunnel (U-42)	07/Jan/1989	Pseudoscorpionida: Chelifreridae	<i>Protochelifer sp., nr P. cavernarum</i>	QM
189/143	Wind Tunnel (U-42)	07/Jan/1989	Blattaria: Blattellidae: Blattellinae	? <i>Paratemnopteryx stonei (Race C)</i>	QM
189/144	Wind Tunnel (U-42)	07/Jan/1989	Coleoptera: Carabidae	undetermined carabid beetle	QM
189/145	Wind Tunnel (U-42)	07/Jan/1989	Hymenoptera: Formicidae: Formicinae	<i>Paratrechina sp.</i>	TMAG
189/146	Wind Tunnel (U-42)	07/Jan/1989	Arachnida: Araneae: Family unknown	undet. spider, possibly Tb	QM
189/147	Wind Tunnel (U-42)	07/Jan/1989	Arachnida: Araneae: Pholcidae	possibly Tb spider (♂, ♀ & juv.)	QM- 88946
189/148	Wind Tunnel (U-42)	07/Jan/1989	Arachnida: Araneae: Pholcidae (?)	undet. pholcid spider	QM
189/149	Wind Tunnel (U-42)	07/Jan/1989	Hemiptera: Reduviidae: Emesinae	undet. reduviid bug	TMAG
189/150	Wind Tunnel (U-42)	07/Jan/1989	Coleoptera: Trogidae	<i>Omorgus sp.</i>	TMAG
189/151	Wind Tunnel (U-42)	07/Jan/1989	Coleoptera: Dermestidae	undet. dermestid beetle	TMAG
189/152	Wind Tunnel (U-42)	07/Jan/1989	Coleoptera: Tenebrionidae	<i>Pterohelaeus sp.</i>	TMAG
189/153	Wind Tunnel (U-42)	07/Jan/1989	Coleoptera: Tenebrionidae	<i>Pterohelaeus sp.</i>	TMAG
189/154	epigeal, outside U-34	07/Jan/1989	Coleoptera: Tenebrionidae	<i>Pterohelaeus sp.</i>	TMAG
189/155	epigeal, outside U-34	07/Jan/1989	Coleoptera: Bolboceratidae	<i>Australobolbus sp.</i>	TMAG
189/156	epigeal, outside U-34	07/Jan/1989	Hemiptera: Belostomatidae	<i>Diplonychus sp.</i>	TMAG
189/157	epigeal, outside U-34	07/Jan/1989	Coleoptera: Scarabaeidae: Melolonthinae	undet. scarab beetle	TMAG
189/158	epigeal, outside U-34	07/Jan/1989	Coleoptera: Tenebrionidae	<i>Ommatophorus sp.</i>	TMAG

Number	Collection site	Date	Higher order classification	Genus species (if known)	home
189/159	epigeal, outside U-34	07/Jan/1989	Isoptera: Mastotermitidae	<i>Mastotermes darwiniensis</i>	TMAG
189/160	epigeal, outside U-34	07/Jan/1989	Diptera: Tabanidae	undetermined horse fly	TMAG
189/161	epigeal, outside U-34	07/Jan/1989	Diptera: Tabanidae	undetermined horse fly	TMAG
189/162	epigeal, outside U-34	07/Jan/1989	Hemiptera: Cicadidae	<i>Illyria burkei</i>	TMAG
189/163	epigeal, outside U-34	07/Jan/1989	Hymenoptera: Vespidae	<i>Polistes sp.</i>	TMAG
189/164	epigeal, outside U-34	07/Jan/1989	Arachnida: Araneae: Family unknown	undetermined spider,	QM
189/165	epigeal, outside U-34	07/Jan/1989	Hymenoptera: Formicidae: Ponicerinae	<i>Anochetus sp.</i>	TMAG
189/166	epigeal, outside U-34	07/Jan/1989	Hymenoptera: Formicidae	undetermined ant	TMAG
189/167	Barkers Cave (U-34)	07/Jan/1989	Blattaria: Blattellidae: Blattellinae	<i>Paratemnopteryx stonei (Race C)</i>	TMAG
189/168	Barkers Cave (U-34)	07/Jan/1989	Crustacea: Isopoda: Oniscoidea	undet. oniscoid isopod (tiny eyes)	TMAG
189/169	Barkers Cave (U-34)	07/Jan/1989	Diplopoda: unknown	undetermined millipede	QM
189/170	Barkers Cave (U-34)	07/Jan/1989	Arachnida: Acarina	undet. microscopic blind mites	QM
189/171	Barkers Cave (U-34)	07/Jan/1989	Collembola: Entomobryidae	undetermined springtail	QM
189/172	Barkers Cave (U-34)	07/Jan/1989	Coleoptera: Scarabaeidae	undetermined scarab beetle	QM
189/173	Barkers Cave (U-34)	07/Jan/1989	Coleoptera: Carabidae	undetermined carabid beetle	QM
189/174	Barkers Cave (U-34)	07/Jan/1989	Lepidoptera: Pyralidae	<i>Pyralis sp., near P. manihoialis</i>	QM
189/175	Barkers Cave (U-34)	07/Jan/1989	Coleoptera: Chrysomelidae: Galerucinae	undet. chrysomelid beetle	TMAG
189/176	Barkers Cave (U-34)	07/Jan/1989	Coleoptera: Tenebrionidae (?)	undet. tenebrionid (?) larva	TMAG
189/177	Barkers Cave (U-34)	07/Jan/1989	Oligochaeta	undetermined earthworms	TMAG
189/178	Barkers Cave (U-34)	07/Jan/1989	Blattaria: Blattellidae	oothecae of cockroach	TMAG
189/179	Barkers Cave (U-34)	07/Jan/1989	Hymenoptera: Formicidae: Dolichoderinae	<i>Iridomyrmex sp.</i>	TMAG
189/180	Barkers Cave (U-34)	07/Jan/1989	Arachnida: Araneae: Nesticidae (?)	undet., possibly ?Nesticella sp.	QM
189/181	Barkers Cave (U-34)	07/Jan/1989	Arachnida: Araneae: Pisauridae	?Dolomedes sp. (♂), possibly Tb	QM-88943
189/182	Barkers Cave (U-34)	07/Jan/1989	Arachnida: Araneae: Nesticidae (?)	undet., possibly ?Nesticella sp.	QM
189/183	Barkers Cave (U-34)	07/Jan/1989	Arachnida: Araneae: Family unknown	undet. spider egg sacs	QM
189/184	epigeal, outside U-17	07/Jan/1989	Coleoptera: Scarabaeidae: Aclopininae	<i>Phaenognatha sp.</i>	QM
189/185	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Formicinae	<i>Polyrhachis sp.</i>	TMAG
189/186	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Ponerinae	<i>Rhytidoponera sp.</i>	TMAG
189/187	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Formicinae	undetermined ant	TMAG
189/188	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Ponerinae	<i>Rhytidoponera sp.</i>	TMAG
189/189	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Ponerinae	<i>Platythyrea sp.</i>	QM ?
189/190	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae	undetermined ant	TMAG
189/191	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Dolichoderinae	<i>Iridomyrmex sp.</i>	TMAG
189/192	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Formicinae	<i>Camponotus maculatus group</i>	TMAG
189/193	epigeal, outside U-17	07/Jan/1989	Formicidae: Pseudomyrmecinae (?)	undet. ant, poss. Tetraponera sp.	TMAG
189/194	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae: Proceratiinae	<i>Proceratium sp.</i>	TMAG
189/195	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae	undetermined ant	TMAG
189/196	epigeal, outside U-17	07/Jan/1989	Hymenoptera: Formicidae	undetermined ant	TMAG
189/197	epigeal, outside U-17	07/Jan/1989	Diptera: Chironomidae	undetermined chironomid	TMAG
189/198	epigeal, outside U-17	07/Jan/1989	SOIL SAMPLE	DISCARDED	
189/199	Pinwill Cave (U-17)	08/Jan/1989	Arachnida: Araneae: Nesticidae (?)	undet., possibly ?Nesticella sp.	QM
189/200	Pinwill Cave (U-17)	08/Jan/1989	Arachnida: Araneae: Nesticidae (?)	undet., possibly ?Nesticella sp.	QM
189/201	Pinwill Cave (U-17)	8/01/89	Arachnida: Araneae: Pholcidae	undetermined spider	QM
189/202	Pinwill Cave (U-17)	8/01/89	Arachnida: Acarina	undet. blind guano mites	QM
189/203	Pinwill Cave (U-17)	8/01/89	Arachnida: Acarina	microscopic eggs of undet. mite	QM
189/204	Pinwill Cave (U-17)	8/01/89	Blattaria: Blattellidae: Blattellinae	<i>Paratemnopteryx stonei (Race C)</i>	TMAG
189/205	Pinwill Cave (U-17)	8/01/89	lepidoptera: Tineidae	undet. moths from tree roots	TMAG
189/206	Pinwill Cave (U-17)	8/01/89	Diptera: Family unknown	undetermined fly larva	TMAG
189/207	Pinwill Cave (U-17)	8/01/89	Diptera: Family unknown	undetermined fly larva	TMAG
189/208	Pinwill Cave (U-17)	8/01/89	Coleoptera: Carabidae	undet. carabid beetle	QM

Number	Collection site	Date	Higher order classification	Genus species (if known)	home
189/209	Pinwill Cave (U-17)	8/01/89	Coleoptera: Histeridae	undet. histerid beetle	TMAG
189/210	Pinwill Cave (U-17)	8/01/89	Crustacea: Isopoda: Oniscoidea	undet. blind oniscoid isopod	QM ?
189/211	Pinwill Cave (U-17)	8/01/89	Hymenoptera: Formicidae: Ponerinae	?Hypoponera sp.	TMAG
189/212	Pinwill Cave (U-17)	8/01/89	Hymenoptera: Formicidae: Formicinae	<i>Prolasius</i> sp.	TMAG
189/213	Pinwill Cave (U-17)	8/01/89	Psocoptera	undetermined psocopteran	TMAG
189/214	Pinwill Cave (U-17)	8/01/89	Coleoptera: Histeridae	undet. histerid beetle	TMAG
189/215	hut on Yaramulla Stn.	08/Jan/1989	Hymenoptera: Formicidae: Formicinae	<i>Camponotus maculatus</i> group	TMAG
189/216	hut on Yaramulla Stn.	08/Jan/1989	Chilopoda	undetermined centipede	QM ?
189/217	hut on Yaramulla Stn.	08/Jan/1989	Arachnida: Araneae: Deinopidae	Deinopis sp. (♂)	QM-88936
189/218	hut on Yaramulla Stn.	08/Jan/1989	Coleoptera: Buprestidae	<i>Merimna atrata</i>	TMAG
189/219	hut on Yaramulla Stn.	08/Jan/1989	Diptera: Tabanidae	undetermined horse fly	TMAG
189/220A	hut on Yaramulla Stn.	08/Jan/1989	Diptera: Family unknown	undetermined fly	QM ?
189/220B	hut on Yaramulla Stn.	08/Jan/1989	Diptera: Family unknown	undetermined fly	QM ?
189/221	hut on Yaramulla Stn.	08/Jan/1989	Arachnida: Acarina	undetermined mite	QM
189/222	Dome Cave (U-41)	07/Jan/1989	Diplopoda: unknown	undetermined millipede	QM ?



Fig. 20. Mick Williams (who accompanied the writer to Undara in January 1989), photographed in January 1989 outside one of the property gates on the road formerly used to access the Undara lava tubes.

Editorial Note: This is a slightly modified version of the paper which appeared in the original version of the Proceedings. Amendments were made June 2011. GJM