AUSTRALIAN NATIVE DUNG BEETLES

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During the 1970s and 1980s, CSIRO ran a well publicised campaign to introduce African dung beetles to Australia to bury and disperse cattle dung. This was done as a means of returning dung nutrients to the soil and breaking the breeding cycle of deleterious organisms such as biting flies, bush flies and intestinal cattle parasites which breed or disperse via unburied cattle dung. More than 40 foreign dung beetle species were released and, of these, 23 species established permanently, covering most of mainland Australia.

Many people, and especially the public, got the idea that this introduction program was undertaken because there were few or no native dung beetles in Australia. This is far from the truth and we know of almost 500 species that are native to Australia. But these native dung beetles evolved on a dry continent where the principal dung source was the dry, hard pellets of marsupial dung and they couldn't deal with the large wet, squishy piles of dung which cattle produce. Having been raised on a dairy farm, I know how they felt!

SIZE OF THE FAUNA

Early in the introduction program, CSIRO realised that the native dung beetles were poorly known, no one having worked on them thoroughly for more than 50 years. A brilliant young American coleopterist, Eric Matthews, fresh from completing a PhD on dung beetles of Puerto Rico, was engaged to review the Australia fauna. He did extensive field work, right around the continent, and eventually published a series of three user-friendly monographs revising the whole Scarabaeinae fauna (Matthews 1972, 1974, 1976) with many new genera and species. To Australia's immense benefit, Eric stayed on in Australia at the South Australia Museum and is still busily working there long after retirement, though tenebrionid beetles became his main focus.

Eric's monographs brought the known Australia native fauna to 284 species. Since then, papers by Eric himself, Zdzislawa Stebnicka (Poland), Chris Reid (Aust. Mus.), Tom Weir (ANIC), the late Ross Storey (Qld DPI) and myself (Qld Mus.) have described another 62 species bringing the described fauna to 346 species. We know of many additional species which still have not been named. To bring uniformity to the way these undescribed species were dealt with in the different museum collections in Australia, Tom Weir and I devised a code name system (e.g. *Onthophagus NQ23*) for them which is now used widely. We currently recognise 128 undescribed species in collections and these bring the total known Australian fauna to 474 species (and counting!) These statistics, broken down by genera, are shown in Table 1.

AUSTRALIAN TRIBES AND GENERA OF NATIVE DUNG BEETLES	NUMBER OF SPECIES. (named+un-named)	
	1976	2015
CANTHONINI		
Amphistomus	18	18+8
Aptenocanthon	2	8
Aulacopris	3	3
Boletoscapter	2	2
Canthonosoma	3	3+1
Cephalodesmius	3	3+1
Coproecus	1	1+1
Diorygopyx	8	8
Labroma	3	3
Lepanus	18	25+59
Mentophilus	2	2
Monoplistes	6	6+2
Pseudignambia	2	2+18
Sauvagesinella	3	3
Temnoplectron	11	16
Tesserodon	8	13
DICHOTOMINI		
Coptodactyla	11	14
Demarziella	11	14+1
Thyregis	4	4
ONTHOPHAGINI		
Onthophagus	165	198+36
TOTALS	**284**	**346+128**

Table 1: Comparison of number of native dung beetles after Matthews' revisions in 1976 with our knowledge in 2015.

DATABASING THE COLLECTIONS

Dung beetles are ideal organisms for survey and environmental assessment. They are easy to sample with baited pitfall traps, they are relatively easy to identify, they are very sensitive to environmental factors such as soil type and vegetation cover, and because of their diet, are linked to the vertebrate fauna. Many countries such as Madagascar and Costa Rica have used dung beetles for county-wide mapping exercises. They've been used as indicators of forest health in Mexico and Brazil, and in altitudinal transect studies in many parts of the world. Recognising this, the Commonwealth Dept. of Environment assisted Australian museums to database their collections and subsequently bought dung beetle data from them. This was merged into a database of around 120, 000 records and I was engaged in 2006 to travel around the museums and do a validation exercise on the data. The Queensland Museum contributed about 70,000 of these records, many of them arising from the massive dung beetle surveys we did in the heyday of Wet Tropics research in the 1980s and 1990s. The QM now has more than 87,000 specimen records.

USING THE DATA

Using this extensive database and mapping resource, it is possible to quickly place local surveys into an Australia-wide context and evaluate their significance. We've found that local bush-care community groups, especially Catchment Care Groups in Queensland are keen to trap dung beetles and get feedback. A QM survey in 2005 located 63 native species in the Greater Brisbane Area. The Catchment Group which covers the suburbs from St Lucia to Kenmore collected 28 species in 2009. A large survey by the Moggill Creek Catchment Group in 2010/11 collected 1385 specimens of 31 species. The report Tania Kenyon and I prepared for them can be viewed at http://www.moggillcreek.org/

wildlife-1/dung-beetle-survey-2010-2011 . Susan Cully and a very small band of helpers collected 13,588 specimens of 43 native and 7 introduced species on the Beechmont Plateau in 2012-14, making it the most diverse area for its size in Australia yet sampled and allowing detailed mapping of the species. An essential component of these surveys by community groups is that everyone has fun, albeit rather scatological fun!!

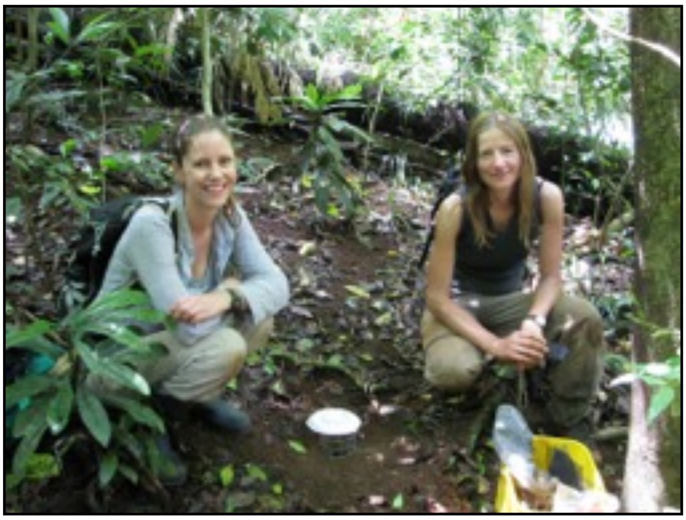

Fig 1. PhD student Mia Derhe (left) and Dr Rosa Menendez, both of Lancaster University, setting up dung in a small vertebrate exclusion cage in the Thiaki rainforest for measurement of dung removal by beetles.

At the more professional level, Rosa Menendez, of Lancaster University in the UK, and I trapped dung beetles during four different seasons along the 20 sites of the big IBISCA altitudinal transect study at Lamington. The 33 species we encountered were highly stratified, with two species totally restricted to small areas above 1000m and thus very vulnerable to climate change. Rosa and I have also been monitoring dung beetle populations every two years on the 64 plots of the big Thiaki regeneration study on the Atherton Tableland where we have found 33 species of which 26 occur in the original rainforest and 16 are in the adjacent cleared grassland. Rosa has postgraduate students working on the Atherton Tableland plots and both Tania Kenyon (Honours, completed) and Mia Derhe (PhD in progress) have been using quantified dung removal monitoring to assess dung beetle impact (Fig 1). Chris Reid (Aust. Mus.) and PhD student, John Gollan, have used dung beetles as indicator groups in vegetation disturbance studies along the Hunter River valley. Without the solid framework of taxonomy and the availability of the enormous background dataset, these projects would not be possible.

WHAT DO DUNG BEETLES DO WITH DUNG?

Adult dung beetles have reduced mandibles and cannot eat solid material, so they just suck up the bacterial "gravy" from moist dung, leaving behind a pile of plant fibres they have licked clean. But the main thing they do with dung is to use it as food for their larvae which DO have functional mandibles and can consume dung in its entirety. Most dung beetles are what we call "buriers". Adults arrive at a dung source and then bulldoze dung down into long nest burrows they

Fig 2. Front view of a male of *Onthophagus tweedensis*. This is a common early season species around Brisbane (Photo: QM).

excavate beneath the dung pile. In the burrow they form the dung into portions, each sufficient to feed a single larva to maturity, and then lay an egg in each. The spectacular horns on the males of many "burier" species are used to defend the nest burrow against invaders and to fight with other males (Fig 2).

Because it gets very "busy" beneath a dung mass when many beetles are competing to dig burrows in close approximation, some species have evolved behaviour which enables them to carry some dung away into a quiet private spot where they can make their brood nest without disturbance. These are the famous "ball rollers" which have curved legs used to shape pieces of dung into balls and roll them away from the source dung pile. In the Australian fauna, the Onthophagini and Coprini are "buriers" while most of the Canthonini are "ball rollers" (Table 1).

Fig 3. Cut-away brood ball showing larva of the African *Sisyphus spinipes* feeding inside. At left is where the female inserted the original egg (Photo: CSIRO).

Inside the dung masses the beetles form in a nest burrow, the hatching larva is C-shaped and grows by feeding round and round in the central chamber of the dung mass (Fig 3). The stored faeces inside the larva's inflated gut is later evacuated and used to seal the empty ball which becomes the pupal chamber.

There are many variations on this basic life cycle plan among the native species and I will mention a few.

THE CUCKOOS

Fig 4. *Demarziella interrupta* (photo: QM)

As in birds, some species have learned to lay their eggs in the nest burrows of other beetles. In Australia, the genus *Demarziella* (Fig 4) is similar morphologically to species that do this overseas and there is one old record of adults being found in the nest of an *Onthophagus* near Toowoomba. We assume that all Australian species probably do this, but more observations would be very valuable.

THE PREHENSILES

Dung beetles need to get to dung while it is still moist and able to be worked. Australia is an arid continent and the already dry dung pellets of macropods dry out very quickly after deposition. About 7-8 Australian species of *Onthophagus* have solved this problem in a remarkable way. The adult beetles have tarsal claws adapted to grip hair and they cling around the anus of macropods. There they wait at the "factory door" and leap aboard as the dung pellets emerge, thus epitomizing Woolworths' "fresh food" slogan! They have been recorded on introduced mammals such as goats and rabbits. One of the species, *Onthophagus parvus* (Fig 5), occurs in

Fig 5. The prehensile species, *Onthophagus parvus.* Note the deeply cleft claw on the right midleg (Photo:QM).

Brisbane's outskirts where nude sunbathing is clearly not recommended. Eric Matthews showed that the specialised prehensile claws (Fig 6) have arisen in two different species groups in Australian *Onthophagus* with a different locking device to anchor the hair in the claw in each group. The resultant claws are remarkably similar to the specialised claws seen in other insects that live among mammal fur, such as fleas and both hippoboscid and streblid flies (Fig 7).

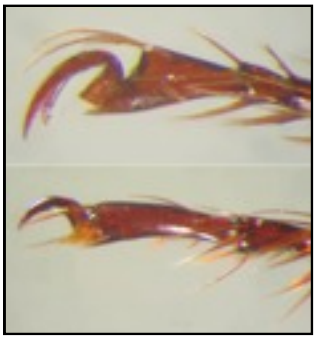

Fig 6. Tarsal claw of *Onthophagus parvus* (top) compared with that of a normal *Onthophagus* species (photo: QM).

Fig 7. Prehensile claws of ectoparasitic hippoboscid (left) and streblid flies

SOME USE MUSHROOMS INSTEAD OF DUNG

Another Australian eccentricity is that a number of species have changed from dung to mushrooms as their source of adult and larval food, either wholly or partly. This has occurred in unrelated species in all three Australian Tribes including several different species groups within *Onthophagus.* Species in both the *dunningi*-group of *Onthophagus* and the canthonine genus *Boletoscaper* (both taxa being entirely mycetophagous) hollow out the stipe (stalk) of mushroom-type fruiting bodies and use it as a tunnel upwards to reach the more nutritious gill material which is taken down to a nest burrow in

Fig 8. *Onthophagus dunningi* male (photo: QM).

Fig 9. *Boletoscapter furcatus* male (photo:QM).

the soil at the base. *Onthophagus dunningi* (Fig 8) and *Boletoscapter furcatus* (Fig 9) are both common in the Brisbane area. The number of mushroom feeding species is much greater in tropical areas of Australia. During surveys we always trap simultaneously with both dung and mushroom baits to make sure we sample the whole fauna.

SOME MAKE THEIR OWN DUNG

Back about 1970, Ross Storey and I were having smoko at our camp table in the Tooloom Scrub, near Woodenbong NSW when, to our amazement, we saw a large dung beetle emerge from a burrow and walk 50cm over the rough leaf litter terrain to a piece of discarded watermelon. It methodically cut off a piece of the red flesh with its toothed forelegs and dragged it (backwards and unerringly) across the obstacle course to the burrow and dragged it inside. We carefully dug the burrow up. It went vertically down about 10 cm then turned at right angles for a short way and ended in a large chamber. Inside were a male and female of the flightless canthonine *Cephalodesmius armiger* (Fig 10), a heap of loose bits of vegetable matter (leaves, small flowers, small fruits and our watermelon piece), a large mass of compacted vegetable matter and about six neat balls of dung-like material each with a larva feeding in the centre.

Fig 10. *Cephalodesmius laticollis,* the largest of the species which make their own "dung" (photo:QM).

Fig 11. A male *Cephalodesmius armiger* dragging a leaf back to the burrow (from Monteith & Storey, 1981).

We had stumbled on what is still known as the most remarkable dung beetle behaviour in the world. We camped at that same spot for a weekend every month for 18 months, scoring the contents of about 20 burrows each time. We found we could set up pairs in glass fronted plaster nests at UQ (where we both then worked), feed them on clover flowers from the lawn of the Great Court and watch the whole process take place. The story was as follows. Mated pairs dug burrows and remained together for nearly 12 months. Males foraged for plant pieces (Fig 11) which the female shredded and squeezed into a large mass which became inoculated with a fungus which converted it to a dung-like consistency. The female then tore off pieces and rolled them into neat balls which she hollowed out to form a thin-walled cup into which she laid a large egg (Fig 12). She then sealed the cup up into a ball again. Each day for about eight days she laid another egg in this way, ending up with a

Fig 12. *Cephalodesmius armiger* hollowing out an egg ball (left) and depositing an egg into it (from Monteith & Storey, 1981).

row of “egg balls”. The larvae soon hatched and started to feed on the internal wall of the egg ball. For the next two months the male continued to bring new plant material to be added to the “compost heap” and the female constantly removed pieces of sticky goo from the heap to plaster on the outside of the egg balls. The balls, and the larvae inside, grew until the balls were much larger than the adult beetles. Thus this was “progressive feeding”, a level of parental care previously unknown in dung beetles. Eventually the larva ejected its stored faeces to the outside through a hole bitten in the wall and the female smeared it over the ball surface where it set to a hard shell while the larva pupated inside. The artificial dung made in the nest was so attractive to other dung breeding insects that we regularly found sphaerocerid flies (Fig 13) and oxyteline

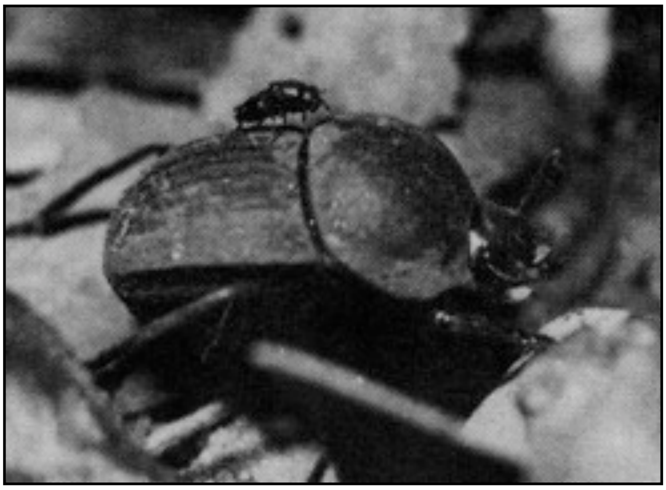

Fig 13. Sphaerocerid fly riding a male *C. armiger* back to the nest so it can lay eggs in the brood mass (from Monteith & Storey, 1981).

staphylinids riding the foraging males back to the nest where they oviposited in the brood mass. Our population estimate showed there were between 20,000 and 50,000 of these beetles per hectare, so they have a significant role in turnover of soil and leaf litter. We also found that all three species of *Cephalodesmius* have the same behaviour. *Cephalodesmius quadridens* occurs in Brisbane suburbs. The whole story is told in Monteith & Storey (1981).

THE BIGGEST DUNG BEETLE LIKES THE SMALLEST DUNG

Our largest native dung beetle is the massive 35mm *Aulacopris maximus* (Fig 14) which was described from specimens collected in the 1920s in a bat cave near Kemsey NSW where a number of large brood balls were collected beside a

Fig 14. Our largest dung beetle, *Aulacopris maximus* (photo:QM).

guano heap. It occurs in normal rainforests without nearby cave systems but breeding activity is not seen. The species comes to rotten mushroom traps more often than dung baits and is often seen crawling on tree trunks at night. Doug Cook has also found an adult under a pile of decaying fungus. The mystery was probably solved by Tony Hiller a few years ago at Mt Glorious when he found an adult with several large brood balls on top of bat guano in the

Fig 15. The *Aulacopris maximus* adult and brood balls found by Tony Hiller (GBM photo).

bottom of a hollow dead tree in which a colony of insectivorous bats had long roosted (Fig 15). The balls are clearly made from bat droppings and are studded with digested insect fragments. Since bat droppings are very dry and do not have the "gravy" which adult dung beetles need to suck up, this may explain why *Aulacopris* seek alternative liquid food from decaying fungus. The adults crawling on tree trunks are probably seeking entry holes to hollow interiors where bats may be roosting.

ANOTHER PROGRESSIVE PROVISIONER?

The genus *Canthonosoma* has three large wingless species which live in the dry vine scrubs of inland central Queensland. One of them extends as far south as the hoop pine scrubs that grew along the Brisbane River but which are now largely gone. This is *C. castelnaui* (Fig 16), for which there are records as recently as the 1950s from the "Ashgrove Scrub". But that rainforest patch is long gone under suburbs and the species seems extinct in Brisbane. The nearest population we know of is in the prickly pine scrubs along the River near Ipswich. There is evidence that this genus is also a progressive provisioner because we have found nests under logs in bottle tree scrubs near Taroom that are lined with dry pulverised macropod pellet material. In the nests were single females of *Canthonosoma macleayi,* each with a set of tiny balls containing eggs or larvae. These would need extra dung added to the surface if there is to be enough food for the larva to feed to maturity. This may be a dry-adaption strategy where females may use one moist macropod pellet to start a batch of egg balls and then wait for the rare chance to get another moist pellet that can be used to enlarge all the existing small balls. If so this will be another unique Australian dung beetle strategy.

Fig 16. *Canthonosoma castelnaui* male (photo: QM).

A MEGA-DIVERSE GENUS

The smallest dung beetles in Australia are the little ball-rollers in the genus *Lepanus* with species as small as 2-3mm. It's our largest genus of ball-rollers with 25 described species. Both the local endemic, high-altitude species we found at Lamington belong to this genus, viz *L. glaber* and the beautiful *L. storeyi* (Fig. 17). Tom Weir at ANIC has long suspected there are many extra unrecognised species of *Lepanus*. In a collaboration with molecular scientist Nicole Gunter (now at Cleveland Museum, Ohio USA) they've done a detailed comparison of morphological and molecular characteristics and have reached the conclusion that there may be around 60 new species, many of them in the Queensland Wet Tropics, and that there may be several generic entities involved. Nicole is planning more molecular studies. Watch this space!

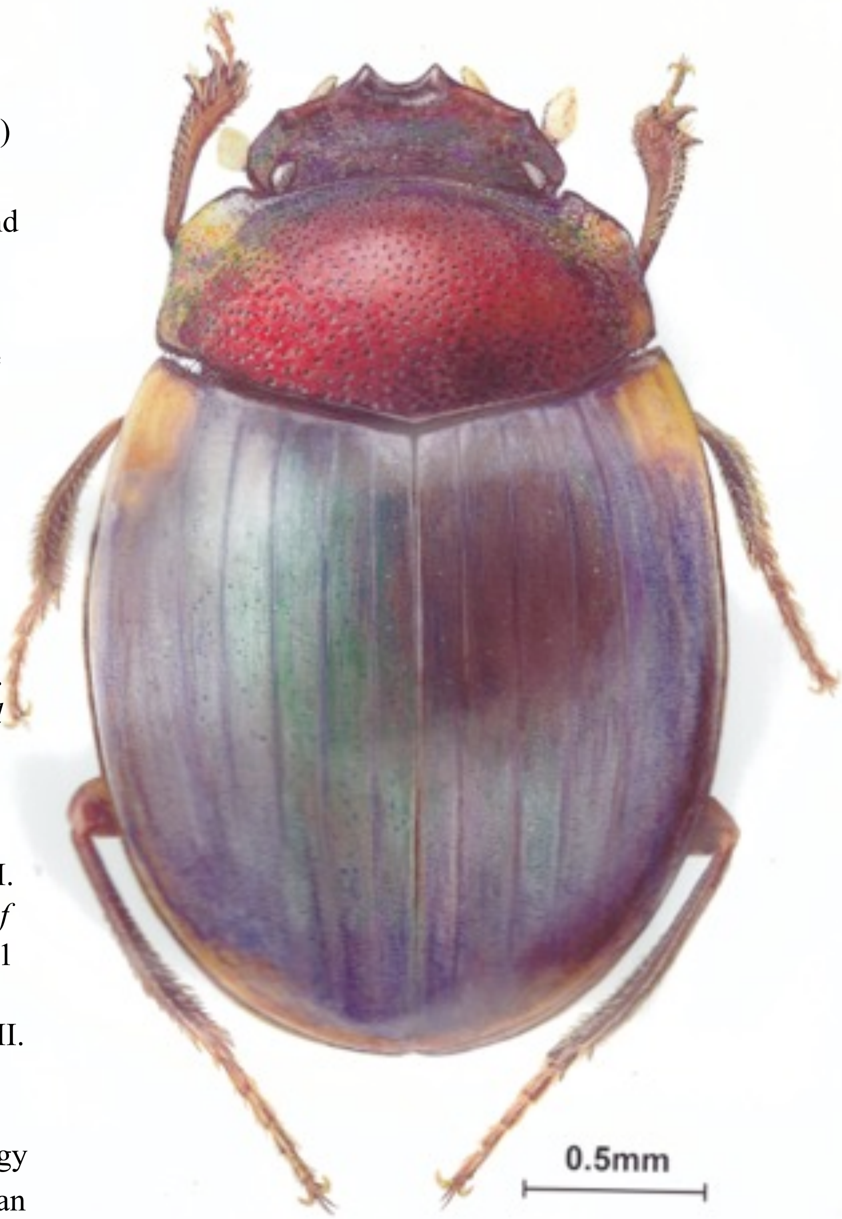

Fig 17. *Lepanus storeyi* (painting: Jacqui Recsei)

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