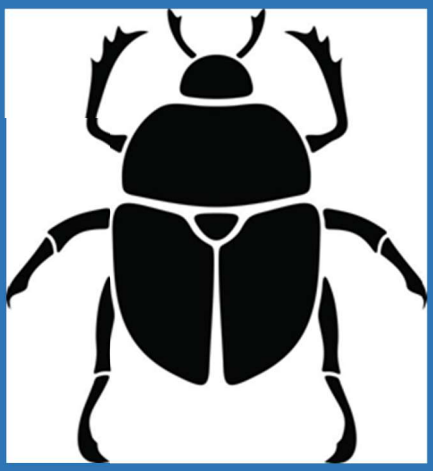
DUNG BEETLES ON THE ATHERTON TABLELANDS: IDENTIFICATION AND LOCATION PROJECT (DBID)

FINAL REPORT OCTOBER 2021



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REMARKABLE nrm

Cape York Natural Resource Management

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Executive Summary

Dung beetles provide a wide range of valuable ecosystem services and these include promoting pasture growth, increasing soil aeration, reducing chemical runoff, soil erosion and dung-dwelling parasite populations. Research on the dung beetle assemblage found on the Atherton Tablelands has been scant in recent times and the most substantial work conducted by Penny Edwards back in 2001. There is a lack of current information about the regional distribution of the established species on the Tablelands and their precise seasonal activity. Furthermore, anecdotal observations suggest that there are seasonal and geographic niches (gaps) in beetle activity that need to be filled in order to achieve a year-round dung burial profile for the Tablelands. Helping to provide this information is the aim of the DBID project and the purpose of this report.

With the help and support of Louise Gavin of Remarkable NRM and financial support from Cape York NRM, four beef producers and two dairy farmers from the Atherton Tablelands collected dung beetles from their farms once a month for 12 months. These specimens were formally identified by Dr Bernard Doube, an expert in the field. A total of 272 dung pads were examined and over 4000 beetles were collected and identified. Overall, there were eight species of introduced dung beetles, two predatory species and a number of native dung beetles. There appeared to be little difference in diversity or abundance of dung beetles between the farms that used chemicals and those farms that did not. However, we did not specifically ask for the frequency or dosage rates of the products, so there could be differences in the frequency of application of these chemicals between farms.

Based on our findings, we would suggest the E intermedius and the D gazella as the two preferred species for a farmer to purchase for the Tablelands if numbers of these species are low (less than 20 per pad). These dung beetles are established across most of Australia and likely to easily obtainable for purchase. Atherton Tableland farmers wishing to purchase dung beetles for release onto their properties would also be advised to first collect a sample of specimens from their property when the dung beetles are visibly active during the onset of summer storms or the rainy season and have them identified by an entomologist. This would provide the farmer with a baseline knowledge of the existent species on their farm for future monitoring of their dung beetle population.

The six farmers involved in the DBID Project have become advocates for the dung beetle; sharing their knowledge with their families, neighbours and peers. We make a number of recommendations at the conclusion of this report. Fundamentally, government and industry research and development funding must be allocated to both understanding and building dung beetle numbers in Northern Australian cattle pastures. This could be coordinated and driven by dung beetle producer and public networks across Northern Australia with the aim of coordinating and driving dung beetle research and development in Northern Australia.

Foreword from Dr Bernard Doube

This study is an excellent example of citizen science in action and backed by scientific expertise. Special acknowledgements should go to Gail Abernethy and Louise Gavin for managing the program and ensuring that we all stayed on board.

This project has taken a most unusual and interesting approach to monitoring the abundance and distribution of dung beetles in relation to cattle farming on the Atherton Tableland. Nearly all published monitoring programs (of which there are dozens in the dung beetle literature) have used dung baited pit-fall traps to monitor beetle abundance. In contrast, this study has directly sampled natural dung pads using the floatation method in which field pads are placed in a bucket of water and the beetles that floated to the surface were collected, identified, and counted. Both methods have advantages and drawbacks.

One advantage of the current method is that only one sampling activity is required per sample, whereas pit fall traps need to be set and collected at different times of day. A further advantage of the current method is that natural dung pads in producer environments are sampled. The disadvantages of the current methodology are that the history of the dung pad sampled (eg its age and time of deposition) is not known and the method of sampling the pad can lead to substantial variations in the number and type of beetle extracted from the field sample. We believe that the vibrations from approaching footsteps can cause beetles to scurry from the pad into their tunnels beneath the pad, thereby escaping collection. The best method is to sneak up, very quietly, and surprise the beetles by quickly slicing a shovel under the target pad, and collecting about one inch of soil in the process. Variations upon this process can also lead to substantial variations in the proportion of the beetle population captured by this method.

Clearly there a number of factors that affect the numbers of beetles found in a pad. These include seasonal factors such as temperature and rainfall that determine whether particular beetle species are active at a particular time of year. For example, in the DBID project, *Onthophagus nigriventris* appears to be spring active while *Onthophagus gazella* appear to have two parallel peaks of

abundance dung the summer sampled. We do not know whether the two peaks are a response to dry conditions between the two peaks or to the appearance of a second generation later in the summer.

Superimposed on top of seasonal effects are the influence of local conditions at each sampling location. Because the sampling sites were dispersed amongst a range of contrasting environments over the Tableland, we may gain important insights into the soil type and rainfall preferences of particular species. These factors will be further examined in the DBID-E project (2021-2022) where 15, rather than 6, locations are being examined. This additional data will allow us to identify types of environments from which particular beetle species are missing. Cropping and redistribution of particular species may be one option to consider to rectify this anomalous distribution. Nearly all the species trapped have been introduced to Australia but there were a series of native dung beetle species associated with cattle dung, albeit in small numbers. Also, I am surprised that there have been no ball rollers present in the trap catches.

Dung beetles, depending upon species, fly to dung during the day, or at dusk and dawn, or during the night. Most dung beetles are strongly attracted to the odour of warm fresh dung and selectively colonise such dung pads. One consequence of this is that the species associated with individual dung pads in one paddock will vary with the time of day at which the pads were produced. For example, late afternoon pads will host many more dusk-fling beetles than pads produced earlier that day. This in part explains why some samples had high numbers of *Onitis* species (dusk-fling beetles that preferentially colonise late afternoon dung pads) while other samples from the same time of year have a predominance of day flying beetles which preferentially colonise dung pads produced in the morning. Fortunately, with a moderate number of sample locations examined each sampling occasion, these differences are averaged-out and we can get a reasonable estimate of population processes, despite the fact that we do not know the time of day at which the pad was produced.

It has been a pleasure to be associated with this project and I thank you all for providing me with the opportunity to assist in the process of describing the seasonal and geographic variations in the dung beetle communities.

Dr Bernard Doube, OAM
Dung Beetle Solutions International
Cave Ave Bridgewater South Australia
27 September 2021

History and Background of Dung Beetles in Australia

Dung beetles consume, bury or scatter dung, increasing pasture growth and potentially reducing negative environmental effects. When the beetles bury dung underground, they take fertiliser (dung) underground, creating holes that help surface water to penetrate the soil, thus reducing runoff and erosion. The removal of dung from a pasture reduces flies and breaks the parasite lifecycle, reducing the need for chemical fly control. For every litre of dung, the beetles relocate underground, a litre of subsoil is rotated to the topsoil. Dung beetles are a food source for a number of animals, including cane toads, and birds such as the ibis and cattle egret. Dung beetles native to Australia consume the small, dry and fibrous dung pellets produced by marsupials (eg kangaroo and wallaby). Native Australian dung beetles are not designed to work on the moister and much larger dung pads of cattle.

Australian livestock produce millions of tonnes of dung (manure) each year. Excessive dung can foul pasture, obstruct plant growth and promote rank unpalatable growth around the edge of dung pats. Dung also immobilises plant nutrients in undecomposed dung pats, retarding the recycling process and increasing the runoff of nutrients and pathogens into waterways. A typical animal on improved pastures produces approximately 20kg of moist dung a day which equates to roughly 5kg of dry matter containing approximately 1.2kg nitrogen, 0.8 kg phosphorus and 0.4 potash[1]. An active and healthy dung beetle population has the ability to bury this dung quickly below the soil surface within several days thereby minimizing nutrient and water runoff from heavy rain events. Cattle dung is also a breeding ground for buffalo fly, native bush fly and biting midges, all known vectors of disease such as bovine ephemeral fever (three-day sickness).

Identifying the need for dung beetles to work specifically on cattle dung, the CSIRO imported 55 species of dung beetles into Australia between 1969 and 1984. Of these 55, 37 were intended for summer rainfall regions of Northern Australia. By 1986, 43 species of these introduced dung beetles had been released into Australia, however only 23 of these species became established in Australia[2]. Between 1990 and 1992, the CSIRO imported an additional four Spanish species to Western Australia, but none of these releases were successful. There have been a number of dung beetle projects in Australia since the CSIRO introduction of dung beetles. The Dung Beetle Crusade Survey (1994-1996) had citizen scientists across Australia collect dung beetles for identification and mapping[3]. The Meat and Livestock Australia (MLA) have also supported a number of dung beetle projects since the 1990s: including:

- a south-east Queensland beetle survey (1999)[4],
- an investigation on the effect of beetles on Southern Australian pasture growth (2007),
- an investigation on the impact of beetles on sheep parasites (2011) and
- the introduction of two European beetle species into South Australia (2016).

In 2019, the Dung Beetle Ecosystem Engineers (DBEE) project, based in southwest Australia, commenced. This project has introduced new dung beetle species to southern Australia, created a beetle identification app, and aims to develop a dung beetle supply and distribution pipeline so more livestock producers can access beetles. A collaborative project with State government, MLA, local Council Catchment Groups, a commercial beetle supplier and two universities, the project has invested significant funding into dung beetle research in southern Australia[5].

[1] Personal correspondence Bernie English DAF
[2] MLA Information Paper Nov 2018
[3] Australia's Introduced Dung Beetles: Original Releases and Redistributions, Tyndale-Biscoe, M. 1996
[4] Dung Beetle Survey of South East Queensland, NAP3.320 Feehan J., MLA. 1999
[5] DBEE website https://www.dungbeetles.com.au/

Queensland Dung Beetle Project 2001-2002

In Queensland, interest in dung beetles appeared to decline following the end of the CSIRO project in the 1980s. Except for the dung beetle survey localised to SEQLD in 1999[4], there was little follow-up to determine the fate of the dung beetles released by the CSIRO. However, a meeting of graziers, scientists, and representatives from government agencies, industry and community groups led the 2001-2002 Queensland Dung Beetle Project[6] (QDBP). This project investigated the distribution and abundance of dung beetles across 117 sites in Qld, increased producer and public awareness about dung beetles, and harvested and redistributed dung beetles across parts of Queensland. Providing the first comprehensive survey of introduced and native dung beetles in cattle dung in Qld, the information acquired during the QDBP was used to select three species for redistribution within Queensland (Onitis caffer, Copris elphenor and Onitis vanderkelleni

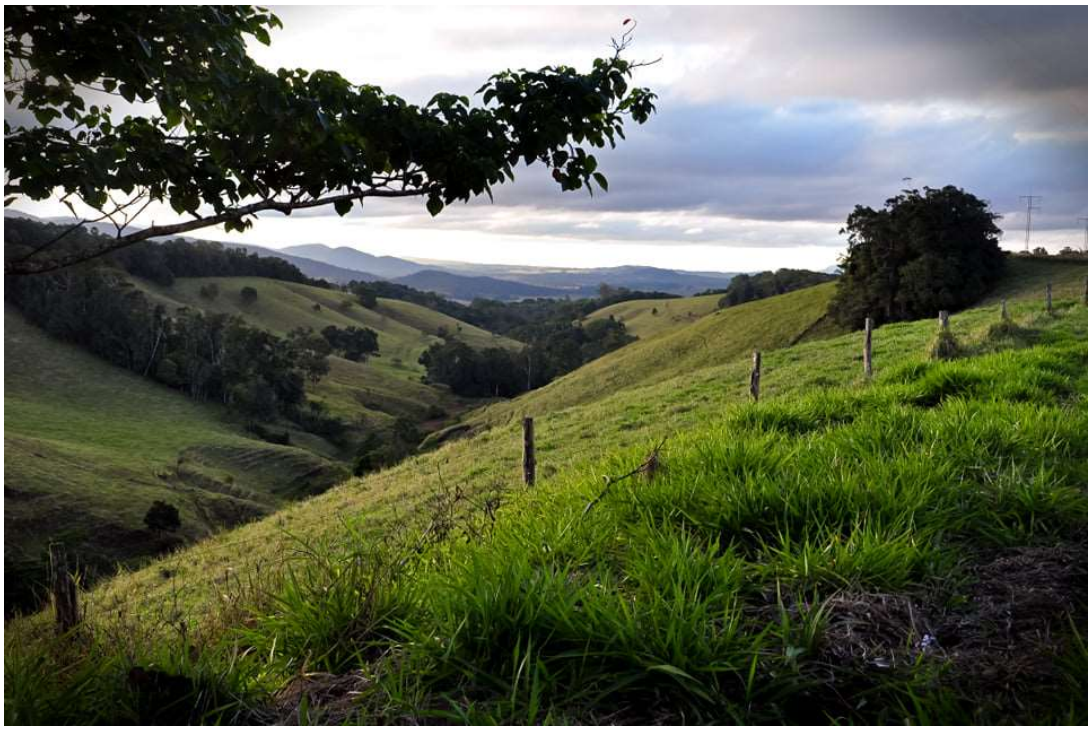


Image: Atherton Tablelands. Photo Credit Tania Torrisi

Two sites on the Atherton Tablelands collected dung beetles for the QDBP: at Ravenshoe and Malanda. There was a total of six introduced species identified with three at both sites: D gazella, E intermedius and O nigriventris. S spinipes and O vanderkelleni were found only at the Ravenshoe site and L militaris only at the Malanda site during the QDBP[5]. Unfortunately, there has been no state-wide coordinated follow up research work on dung beetle distribution in Queensland since the QDBP. There have however, been some small-scale projects done at a producer level by Landcare groups or farmer networks such as the Malanda Beef Plan Group on the Atherton Tablelands.

[6] Final Report of the 2001-2002 Queensland Dung Beetle Project. Penny Edwards.

Dung Beetles on the Atherton Tablelands

Covering an area of 64,768 square kilometres, the Atherton Tablelands is situated in Far North Queensland about 90 minutes' drive east of Cairns and is home to 45,243 people (estimated resident population, Census 2011). The region spreads westwards and southwards from the coastal escarpment behind Cairns and there are five broad climatic zones[7] reflecting the considerable diversity in elevation, rainfall and soil types within the Tablelands region. The northern area enjoys cool, dry winters and warm, wet summers with minimum daily temperatures in winter rarely falling below 15ºC and maximum daily summer temperatures rarely exceeding 35ºC. To the south, temperatures are lower with a range of between 17 and 25ºC from September to June and between 0 and 14ºC from July to August.

While the region is situated in the tropical zone, with a distinct wet and dry season, there is rainfall variability within the region. Rainfall is much higher in the southern Tablelands; for example, at Topaz, which has some of the highest annual rainfall in Australia. The Tablelands are crisscrossed with numerous permanent and semi-permanent creeks, rivers and streams which drain into the Great Barrier Reef. Most, if not all, grazing properties on the Tablelands have at least one water course within its boundary[8]. The Atherton Tablelands is a highly productive agricultural region with a wide range of cropping and animal industry activity.

Image: Atherton Tablelands. Photo Credit Tania Torrisi

[7] Soils and agricultural land suitability of the Atherton Tablelands North Queensland 1999, Malcolm, Nagle et al
[8] Personal correspondence Bernie English DAF

Eleven species of introduced dung beetles were released by the CSIRO at several sites across the Atherton Tablelands during the original distribution in the 1970s (Table1)[9]. Colony sizes varied between the release sites ranging from 220 to 1500 individual beetles per release[3]. Dung beetle surveys were conducted nationally following the CSIRO release (April 1980 and the Dung Beetle Crusade during the summer months of 1994-1995) to discover how successful the initial releases had been, and included sites on the Atherton Tablelands. These two surveys were held at different times of the year, and at one time point, so the results may not reflect the actual activity nor abundance of every species. At the CSIRO Atherton releases: *O alexis, O foliaceus* and *E africanus* were not found during the later surveys, and *H nomas* and *O vanderkelleni* were not found at the Mareeba sites. There were only two sites on the Atherton Tablelands which contributed to the 1994-1995 Dung Beetle Crusade, and both *D gazella* and *O nigriventris* specimens were identified.

Table 1: Summary of CSIRO releases and identification on the Atherton Tablelands 1976-1980

Location (number of CSIRO release sites	Species	Number of CSIRO sites where beetles were release	number of CSIRO sites where beetles were identified after release
Atherton (8)	D gazella	7	6
	O nigriventris	5	5
	O vanderkelleni	5	1
	E intermedius	6	6
	H nomas	6	6
	O foliaceus	4	0
	O alexis	2	0
	O viridulus	1	1
	L militaris	1	1
	E africanus	1	0
Yungaburra (3)	D gazella	1	1
	O nigriventris	1	1
	E intermedius	1	1
Mareeba (4)	D gazella	4	4
	E intermedius	3	3
	H nomas	1	0
	O vanderkelleni	1	0
	O sagittarius	2	2

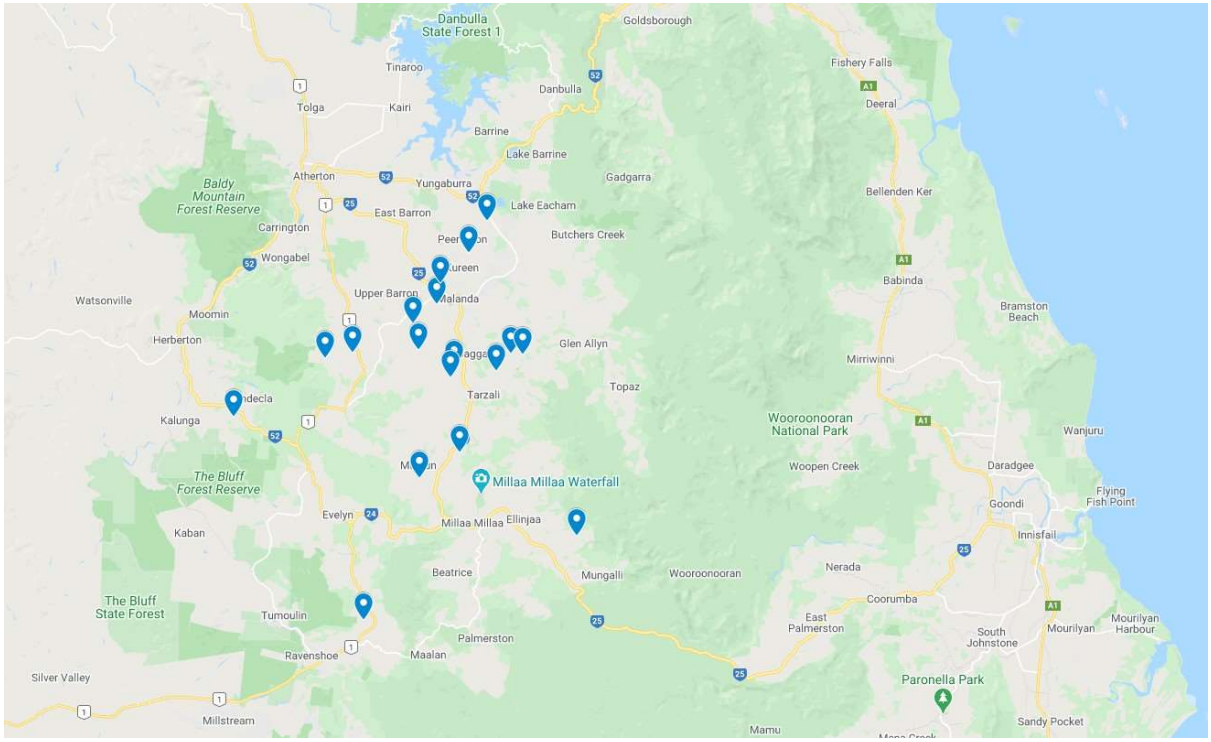
Today on the Atherton Tablelands, most of the intensive beef and dairy properties are situated around Malanda and to the south of Atherton with approximately 500 beef and dairy producers running 90,000 head of cattle[10]. The Malanda Beef Plan Group is a cattle producer network on the Atherton Tablelands.

[9] Australia's Introduced Dung Beetles: Original Releases and Redistributions, Tyndale-Biscoe, M. 1996
[10] Personal correspondence Bernie English DAF

Malanda Beef Plan Group Dung Beetle Project 2014-2016[11]

The Malanda Beef Plan Group (MBPG) is a group of Tableland beef producers who meet regularly to exchange ideas and promote the industry. In 2014 the group hosted a farm field day which included a presentation from John Feehan (SoilCam Pty Ltd), one of the few commercial dung beetle suppliers in Australia. The MBPG subsequently obtained a Landcare grant through Terrain NRM to purchase and release a number of dung beetle colonies onto Atherton Tableland dairy and beef farms. A series of training and awareness days were conducted by the MBPG for producers receiving beetles about how to introduce the beetles and beetle-safe farm management practices. Beetles were sourced from SoilCam Pty Ltd (Canberra) – the only supplier of beetles to Far North Queensland at that time, and the species of dung beetle delivered was selected by John Feehan. The severe drought across Eastern Australia during 2015 caused supply difficulties so the first dung beetles did not arrive until January 2016.

Six different species of beetles were released across 18 Tableland properties from January to May 2016. All but one property received *D gazella* (17/18 properties) and most received *E intermedius* (11/18 properties) and *O alexis* (11/18 properties). See Map 1 for locations of MBPG Dung Beetle Project release sites. Due to supply issues, the release numbers of three species (*E africanus, S rubrus, S spinipes*) were low (less than 1000 in total per release). Unfortunately, there was no baseline beetle species identification undertaken for the 2016 MBPG Dung Beetle Project prior to release of the purchased beetles so there is no way of knowing if the species was already on the property prior to release of the purchased beetles. There was no follow up to the MBPG Project conducted so it is unknown if the dung beetles established at these properties.



Map 1: MBPG Dung Beetle Project release sites 2016 (blue balloon indicates a beetle release site)

[11] Malanda Beef Plan Group Report "Dung Beetle Project" 2016

DBID

Dung Beetles on the Atherton Tablelands:
Identification and Location Project 2020-2021

AIM

to identify what species of dung beetles are established on the Tablelands

to determine their activity over one year

to increase awareness about dung beetles

Dung Beetles on the Atherton Tablelands: Identification and Location Project (DBID)

Background

Remarkable NRM has partnered with local communities and interest groups to develop their skills and ability to collaborate with Government bodies on projects aimed to improve regional community sustainability and environmental outcomes. In October 2019, Louise Gavin from Remarkable NRM networked a group of Atherton Tableland beef and dairy producers (The Beef and Dairy Network Group) and facilitated a series of meetings to enable the exchange of information and ideas among the members. One of the key areas of producer interest was dung beetles and the need for further work to be undertaken in the region. This producer led discussions prompted the project: *Dung Beetles on the Atherton Tablelands: Identification and Location*.

Dung Beetles on the Atherton Tablelands: Identification and Location (DBID) was an eighteen-month research and extension project which acknowledged and built on the important work conducted in previous years on the Atherton Tablelands, and throughout Queensland. A collaborative DBID Team evolved from the Beef and Dairy Network Group, Remarkable NRM, and the Malanda Beef Plan Group to coordinate the project.

The project aimed to:

1) Identify dung beetle species currently established on the Atherton Tablelands,
2) Determine the relative activity levels of the beetles over 12 months (including all seasons),
3) Increase producer awareness of the ecosystem services dung beetles provide and their potential benefits to production,
4) Contribute to the Australian Living Atlas database, and
5) Contingent on funding: purchase a winter season species and monitor their activity and potential propagation into new areas over 2021-2022.

Five of the DBID Farmers and Louise Gavin (Remarkable NRM) (missing from photo Farm PCG)

Project Description

A project plan and description were prepared prior to commencement of the project and included an itemised budget, key dates and timeframe for activities and clear descriptions of participant roles and responsibilities. Funding to the value of $16 500 was obtained from Cape York NRM for project activities and subsequently managed by Remarkable NRM. Beetle identification was undertaken by one of the leading Australian experts in dung beetles, Dr Bernard Doube. Project coordination and communication was overseen by Louise Gavin (Remarkable NRM), on farm soil testing by Paul Edwards (Sweeter Soils) with data entry and analysis coordinated by Gail Abernethy (threechookfarm).

Six farmers from the Dairy and Beef Network Group volunteered to be part of the project: with farmers from either a beef or dairy operation utilising a range of on-farm management practices, including one biodynamic farm. Specific details about each property are provided in the results section.

Based on the published literature, previous hands-on experience, and collection advice from John Feehan's website[12], Gail Abernethy (GA) provided Louise Gavin (LG) and Paul Edwards a practical, on-farm demonstration about how to collect and process the dung beetles for transport. Paul Edwards and LG provided one-on-one education to each participant to ensure consistency of specimen collection and packaging among the participants. Prior to commencement of beetle collection, Paul Edwards collected soil samples to obtain a baseline microbiology assessment of each property. Participants were provided with a DBID Project Pack, consisting of information about dung beetles and dung beetle safe chemicals, detailed information about how to collect and process beetles for transport, and packaging and postage materials. Dung beetle specimens were collected from each property at the same time of day and at the same time of month (eg the first Tuesday of each month at 10am) on a schedule which was convenient to the individual farmer.

The floatation collection method is used in scientific studies and recommended on the SoilCam website for collecting dung beetles. This method was selected for the DBID Project as an economic option and the most practical for non-scientist farmers. Beetles were collected from four individual dung pats estimated to be at least 24hours old, and up to 72hours old to enable both day and night flying beetles to have access to the dung. Where possible, a scraping of dirt from below the dung pat would be included in the collection for any beetles moving underground. The dung pat, soil and any grass were then placed in a water filled bucket. The content of the bucket was stirred to break up the dung pat and the dung beetles collected as they appeared on the surface.

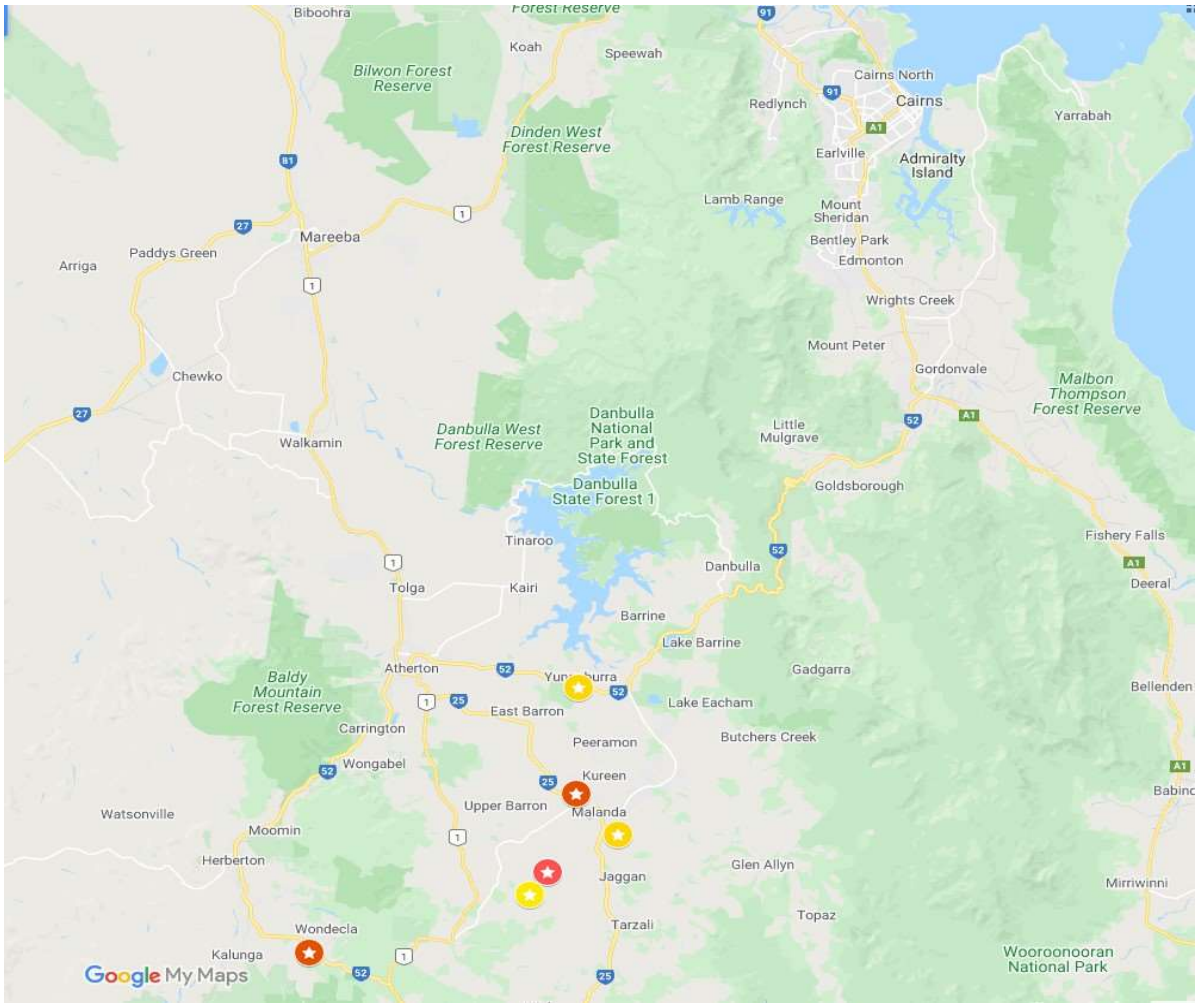
[12] https://dungbeetleexpert.com.au/dung-beetle-information/identifying-dung-beetles/

The beetles were then killed in either hot water or a weak alcohol solution, and left to dry out of direct sunlight. The dried specimens were then packaged into Australia Post CD cases and posted to Dr Doube in South Australia for identification. Dr Doube reported the identification details via email directly to LG for entry into the database, and the results were disseminated in tabular format via email to the participants. Participants reported beetle activity, rainfall trends and farm management information including: farm chemical and herbicide usage, rainfall estimates, at quarterly intervals to LG, and the information entered onto a database by GA.

Ongoing project updates to participants were provided by LG in-person, and through regular email and phone contact. LG and GA provided project updates at MBPG meetings. Remarkable NRM facilitated a workshop on September 4 2020 at Malanda, providing project information and summary results to that date to the group and members of the public. Unfortunately, due to COVID-19 restrictions, attendance numbers were limited and the event was oversubscribed. A meeting with project participants and Dr Doube (via telephone) was held at Yungaburra in March 2021 to discuss the identification results and findings to that date, and to discuss future projects.

Participant Farm Information

The information about each farm that is reported here has been provided by the owner. Five properties are located in the Malanda – Yungaburra region and one is more westerly near Wondecla (Map 2). One DBID farmer had previously conducted some beetle identification ("Farm Wondecla"), and was one of three properties which received beetles in the MBPG Project (the other two DBID properties being Farm PCG and Farm Biodynamic) (red stars on Map 2).



Map 2: DBID Project sites (red and yellow stars markers on map) in relation to Cairns

Farm Wondecla: 'threechookfarm'

'threechookfarm' is located in Wondecla approximately 10km south of Herberton on the Atherton Tablelands. The 90-acre property was purchased by the current owners in 2012 to fatten store steers for the local butcher market. The neighbouring properties also run beef cattle. During World War II, the property was a staging base for an Australian armoured tank division. Prior to, and following the war, the property was used for corn and potato cropping and, then from at least the early 2000s, for beef production. The climate is semi-temperate with a wet and dry season, however at 980m above sea level, the winters are cool with at least one frost day per year. The average rainfall (2013-2020) is 1100mm with the majority of the rainfall occurring during January to March.

The property soil type is Kaban (red clay loam) on a slightly sloping block[13]. Since 2012, regular soil testing has been undertaken and a program of re-seeding, fertilizing, liming and ripping. Fertiliser application occurs annually during the summer. The owners have significantly reduced the volume and variety of weeds in the pastures using either Starrane or Roundup as determined by the type of weed to the point now that the owner now can remove individual weeds by hand when inspecting the pastures.

The property runs two horses, and 30-40 head of steers. Stock numbers and grazing rotation through the paddocks is determined by the condition and growth cycle of the grasses. The stocking rate is also regulated in anticipation of winter frost damage to the pasture. A mob of 10-20 kangaroo regularly visit the paddocks and there are frequent sightings of native bettong and bandicoots throughout the year. There are also a number (9-15 head) of laying chickens which free range across the property, including into the paddocks. Wild birds, including ibis and cattle egret, are frequent visitors to the property and some cane toads are found in the paddocks.

Cattle weaners brought onto the property are wormed with Cydectin and kept separated from the main herd for a minimum of one week. To protect the cattle from buffalo fly, the cattle have access to a back rub at most times of the year. ExiGuard (Chlorfenvinphos@200g/L) chemical is added to the back rub oil when flies are obviously visible and annoying the cattle. Cydectin Pour-On may also be used if deemed appropriate for high fly or tick burden on the cattle, however this is rarely required. Cattle are vaccinated for Three Day Fever prior to the onset of the wet season. Faecal worm counts conducted on the horse manure at regular intervals by the local veterinary service have shown no requirement for worming since June 2015. However, the horses are rotationally wormed for tapeworms, bots, ascarids, and pinworms which do not show up in faecal counts.

Following the presentation by John Feehan at the Malanda Beef Group Field Day in 2014, the owners sent a sample of farm dung beetles (collected by the floatation method) for identification, then purchased dung beetles recommended by John Feehan. The owners are MBPG members and were participants in the 2016 dung beetle project. Identification of a one-off collection of dung beetles was conducted by a Department of Agriculture and Fisheries entomologist prior to the MBPG release in 2016. Beetles identified and released on this property (2014-2016) are listed in Table 2.

Table 2: beetles identified and released on Farm Wondecla 2014-2016

Beetles Identified pre-release 2014	Beetles Released 2014	Beetles Identified pre-release 2016	Beetles Released 2016 (number)
O viridulus	O. binodus (500)	O vanderkelleni	O alexis (1000)
O nigriventris	O. taurus (500)	O sagittarius	E intermedius (1000)
E intermedius	O. fulvus (500)	L militaris	D gazella (1000)
H nomas		unspecified natives	3 species mixture (500 total)
unspecified natives			

[13] https://www.publications.qld.gov.au/dataset/soils-atherton-tab/resource/80c7ace9-46e4-4a6f-b61a-adc82a1b6d9b

Farm PCG: 'Petersen & Co Grazing'

This property is located on the Merragallan Road, Upper Barron region. The property was used for dairying, and then goats and beef cattle, prior to the current owners purchasing the land 10 years ago. The land area is 125 acres with some hilly and sloping areas, and is used to fatten mixed cattle for the market. The neighbouring properties run beef cattle or dairy. The current owners are in the process of planting over 5000 native trees in addition to the established rainforest along the creek. The climate is semi-temperate with a wet and dry season, however at around 805m above sea level, the winters are cool with an occasional frost in the lowest paddock. The average rainfall is 1800mm with the majority of the rainfall occurring during January to March.

The property is divided into paddocks for rotational grazing and runs 100 head of mixed breed cattle, some sheep and chickens. Pastures are fertilised, ripped and or re-seeded as determined by the owner. Stock numbers and grazing rotation through the paddocks is determined by the condition and growth cycle of the grasses. Wild birds, including ibis and cattle egret, are frequent visitors to the property and cane toads are found in the paddocks. Native marsupials are very rarely seen in the paddocks.

Cattle parasites such as buffalo fly, ticks and worms are managed with Maximus (moxidectin), Tixfix (Flurazon 25g/L), an Insect Growth Regulator (IGR) and Supona (Chlorfenvinphos 200 g/L, liquid hydrocarbons 642.6 g/L as solvent) when required. The owners are MBPG members and were participants in the 2016 dung beetle project, and dung beetles released on this property were O alexis, and D gazella. The soil type is Pin Gin and this property is situated on the same road, and the same side of the road, as Farm Platypus Creek.

Farm "Malanda"

'Farm Malanda" is located near Malanda, elevation approximately 757m on a sloping block with a scattering of shade trees throughout the property. The owners have been dairy farmers on this property for over 30 years and run approximately 240 cows on 450 acres (which includes 80 acres of irrigated pasture). The pastures are a mixture of grasses (Seteria, Brachiaria), legumes (pinto peanut, clover) and winter ryegrass and chicory. Urea is applied up to 8 times per year with CK66 applied annually on the irrigated ryegrass. The soil type is Pin Gin and the property can get frost during winter. Cane toads, cattle egret and ibis are regularly seen in the paddocks in large numbers, with a number of wallabies at the back of the farm (only two samples taken from this area during the DBID Project). The neighbouring properties run beef cattle. This property is on the opposite side of the Malanda township to Farm Biodynamic.

Farm FTW: "Fig Tree Wagyu"

'Fig Tree Wagyu" is located between the township of Yungaburra and the Curtain Fig Tree rainforest and was used as a dairy farm up until the 1970s, when it transitioned to beef cattle production and biodynamic farming practices. The owners have produced Wagyu cattle for the past 22 years for their smaller stature and lesser grass intake compared to the larger type cattle.

The soils are volcanic red, dark, and clay types, and the relatively flat pastures are mix of tropical grasses, with rye, oats, clover, medics and plantain planted for winter forage. The property is divided into paddocks for rotational grazing and the paddocks have solid set irrigation to provide water to the pastures during the dry periods. In the past, chickens were introduced onto the pastures to provide fertiliser, control weeds and scatter the cattle dung. The Curtain Fig National Park adjoins the property.

The climate is semi-temperate with a wet and dry season, however at around 708m above sea level, the winters are cool with heavy and light frosts possible (the lowest temperature in 2020 was recorded by the owner at -5^0C). Rainfall is variable as the property is in a rain shadow with annual rainfall between 660-1200mm (the majority of the rainfall occurring during January to March).

Farm "Biodynamic"

'Farm Biodynamic" is located near Malanda, elevation approximately 744m, on a sloping block with some shade trees throughout the property. This property is located on the opposite side of the Malanda township to Farm Dairy, and the neighbouring properties run beef cattle. The property was also a dairy farm prior to the current owners taking over the operation 13 years ago. The current owners have 200 head of dairy cattle on 300acres and supply biodynamic milk to Mungalli Dairy. The paddocks are red basalt soil and have a mixture of Bracchiaria, Seteria, pinto peanut and Vigna legumes and grasses. The property is irrigated during the dry season and frosts do occur in the winter. Wallabies are regularly seen in the paddocks in the dry season and egret, ibis and cane toads are also seen during the year. One colony of both *E intermedius* and *D gazella* were released onto this property as part of the MBPG dung beetle project in 2016.

Farm "Platypus Creek"

This property is located on the Merragallan Road, Upper Barron region on the Atherton Tablelands. The property was used as a dairy farm from the 1930s until transitioning to beef cattle 10 years ago. The current owners purchased the property as a beef cattle farm in 2016. The land area is 220 acres with some hilly and sloping areas and is used to breed beef cattle for the re-stocker market. The neighbouring properties also run beef cattle or dairy herds. There are numerous trees throughout the property providing shade to the animals.

The climate is semi-temperate with a wet and dry season, however at around 832m above sea level, the winters are cool, but do not get frost. The average rainfall is 1800mm with the majority of the rainfall occurring during January to March.

The property is divided into paddocks for rotational grazing and runs 110 head of Brangus breeding cows, and chickens. The pastures consist of Seteria, Brachiaria and legumes and grazing rotation through the paddocks by the cattle is determined by the condition and growth cycle of the grasses. Wild birds, including ibis and cattle egret, are frequent visitors to the property and cane toads are found in the paddocks. Native marsupials are very rarely seen in the paddocks. The owner does not use cattle drenches or wormers but does provide the cattle an ExiGuard back rub for buffalo fly and a tick treatment when necessary. The soil type is Pin Gin and this property is situated on the same road, and same side of the road, as Farm PCG.

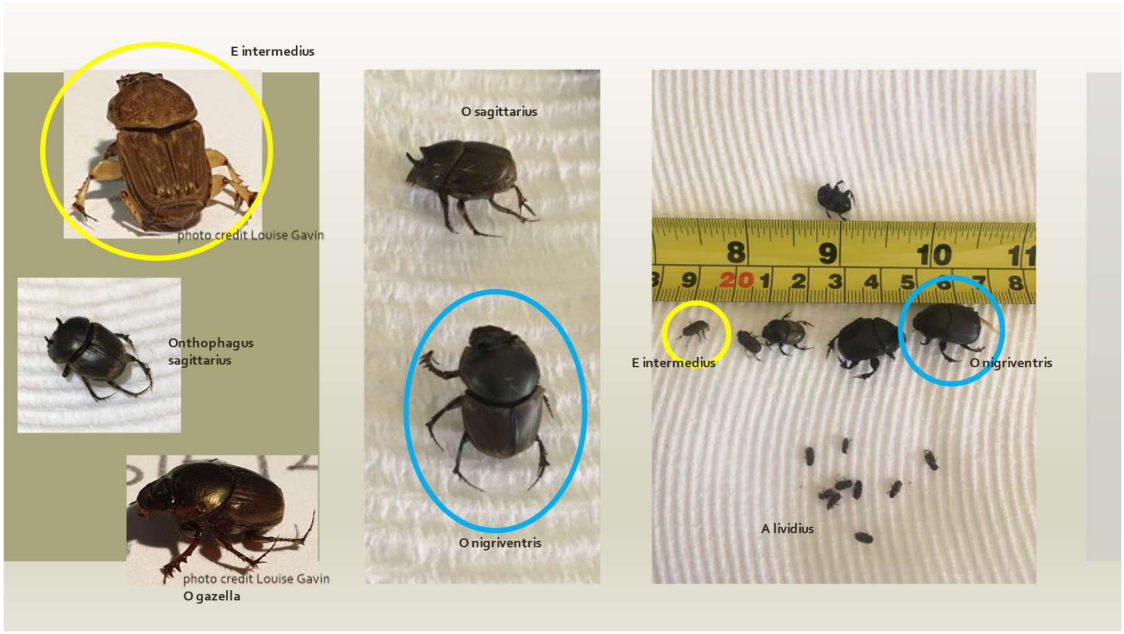
Floating the dung beetles for collection and identification

Results

For the purposes of this report, we recognise six distinct species groupings. These are

- Group 1: Medium sized species with a widespread subtropical geographical distribution. These are D *gazella, E intermedius, L militaris.*
- Group 2: Medium sized species with a highly restricted coastal high rainfall distribution. These species are *O nigriventris* and *O sagittarius*.
- Group 3: Large *Onitis* species; the *O viridulus* with a widespread subtropical geographical distribution and O *vanderkelleni* with a highly restricted coastal, high rainfall distribution.
- Group 4: Very small sized *Aphodius* species; the *A lividus* and the *A fimetarius*.
- Group 5: Predatory species which consume the eggs and larvae of dung breeding flies, these include *H nomas* and *S bicolour*[14]
- Group 6: Native species of dung beetle.

In this report, we focus primarily on the introduced of dung beetle species with a minor assessment of the native dung beetles.



Beetle Identification, Seasonality and Abundance: Overall Trends and Findings

Over the 12 months of the study a total of 272 dung pads were examined and over 4000 beetles were collected and identified. Overall, there were 8 species of introduced dung beetles, two predatory species and 17 species of native dung beetles (none of which were abundant) (Tables 3, 4, 5).

There were distinct differences between farms with regard to activity and abundance of the introduced dung beetle species, however, some general trends and similarities across all farms were found. Seven species (*D gazella, L militaris, O sagittarius, O vanderkelleni, A lividus, H nomas, S bicolour*) were found on all six farms at least once in the 12-month collection period (Tables 3,4).

[14] S bicolour is also referred to as S discolour in some texts. For this report, we use S bicolour

Table 3: DBID Identification (Groups 1-3) by Site: May 2020 to April 2021

E intermedius	***L militaris***	***D gazella***	***O nigriventris***	***O sagittarius***	***O vanderkelleni***	***O viridulus***
	Platypus Creek	Platypus Creek	Platypus Creek	Platypus Creek	Platypus Creek	
Malanda	Malanda	Malanda	Malanda	Malanda	Malanda	
Farm FTW	Farm FTW	Farm FTW		Farm FTW	Farm FTW	
Biodynamic	Biodynamic	Biodynamic	Biodynamic	Biodynamic	Biodynamic	Biodynamic
Farm PCG	Farm PCG	Farm PCG	Farm PCG	Farm PCG	Farm PCG	
Wondecla	Wondecla	Wondecla	Wondecla	Wondecla	Wondecla	Wondecla

Table 4: DBID Identification (Group 4 and 5) by Site: May 2020 to April 2021

A lividus	***Aphodius spp2***	***Aphodius spp10***	***A fimetarius***	***H nomas***	***S bicolour***
Platypus Creek				Platypus Creek	Platypus Creek
Malanda		Malanda		Malanda	Malanda
Farm FTW	Farm FTW		Farm FTW	Farm FTW	Farm FTW
Biodynamic				Biodynamic	Biodynamic
Farm PCG		Farm PCG	Farm PCG	Farm PCG	Farm PCG
Wondecla			Wondecla	Wondecla	Wondecla

Farm Wondecla had the most diverse range of native beetles of all the farms: 11 different native dung beetle species were found over the 12 months of collection. Farm Wondecla reported regularly having 15-20 head of kangaroo visitors in their paddocks which may account for the variety of native species of dung beetles on this farm.

Identification of the native species collected in the DBID Project is tentative at the time of this report and will be verified by Dr Geoffrey Monteith of the Queensland Museum.

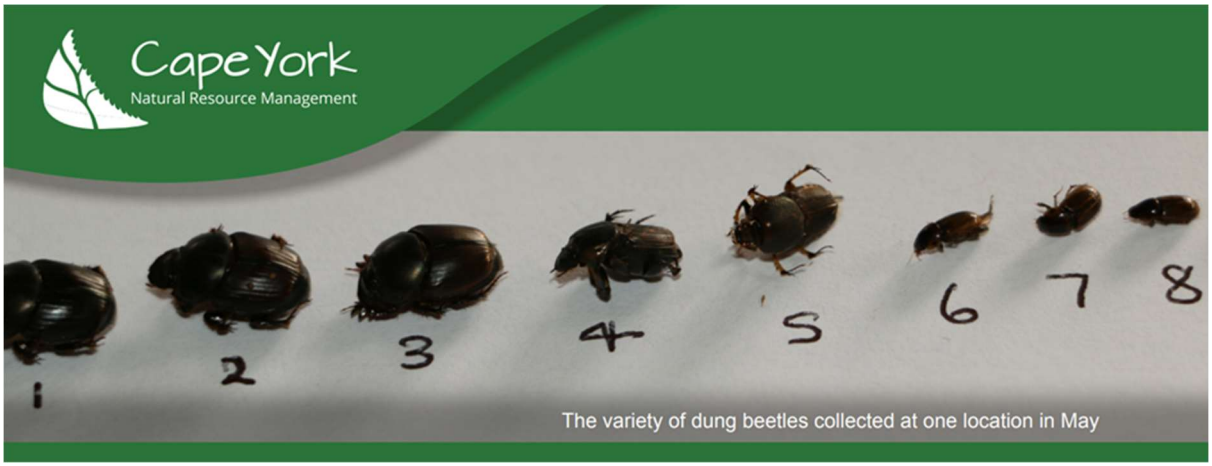
Table 5: DBID Identification (native dung beetles) by Site: May 2020 to April 2021

O spp1	***O spp1c***	***O spp3***	***O spp4***	***O spp5***	***O spp6***
			PlatypusCr		*PlatypusCr*
			Malanda		
	Farm FTW				
Biodynamic			*Biodynamic*		
Farm PCG					
Wondecla	*Wondecla*	*Wondecla*	*Wondecla*	*Wondecla*	*Wondecla*
O spp7	***O dandalu***	***C monstrosa***	***O thoreyi***	***O spp13***	***O spp14***
				Malanda	
	Biodynamic		*Biodynamic*		
					Farm PCG
Wondecla		*Wondecla*	*Wondecla*	*Wondecla*	
O spp15	***O spp16***	***O spp17***	***O spp20***	***O parvus***	
				Malanda	
	Farm FTW	*Farm FTW*			
Biodynamic					
Farm PCG			*Farm PCG*		
	Wondecla				

It was rare for every farm to collect the same species in the same month (Table 6). The only species found on all farms in the same month was *A lividus*, however *O vanderkelleni* and *H nomas* were found on five out of five farms (as only five farms collected beetles in those months (yellow shaded in Table 6)). NOTE: numbers of dung beetles in this report are total number collected from four cattle pads, unless otherwise stated.

Table 6: DBID: May 2020 to April 2021 Number of farms that had each species per month (maximum = 6, except for months * when only five farms collected beetles)

	May*	**June**	**July**	**Aug**	**Sept***	**Oct***	**Nov***	**Dec**	**Jan2021**	**Feb**	**Mar**	**Apr**
E intermedius	3	3	2	2	1	1	1	4	2	4	2	2
L militaris	2	3		1	2	1	3	2	4	4	5	4
D gazella	2					2	2	5	4	3	4	5
O nigriventris	2	2	3	2	3	2	1	2	2	5	2	2
O sagittarius	4	3	2	2	1	2	2	2	4	4	3	5
O vanderkelleni	2			1	1	3	5	3	1	4	4	1
O viridulus				1	2	1		1				
A lividus	1	4	3	3	4	5	4		1	5	6	6
Aphodius spp2		1	1									
Aphodius spp 10			1							1		
A fimetarius	1			2	1			1			1	
S bicolour	4	4	3	2	2	4	2	4	4	5	5	5
H nomas	1	3	3	5	5	4	2	3	1	4	3	3



Whilst the numbers of dung beetles collected each month were small, there was an overall increase in the numbers collected with the onset of the summer storms and rain in October - November (Table 7, Figure 1, 4).

Table 7: DBID: May 2020 to April 2021 ***Total*** number of introduced dung beetles and other beetles found in dung collected from all farms per month (maximum number of farms = 6 farms, except for months * when only 5 farms had beetles identified)

	May*	**June**	**July**	**Aug**	**Sept***	**Oct***	**Nov***	**Dec**	**Jan2021**	**Feb**	**Mar**	**Apr**
E intermedius	46	87	14	3	14	44	31	21	59	18	5	25
L militaris	7	6		3	4	10	33	36	212	44	37	199
D gazella	5					5	27	19	146	38	47	96
O nigriventris	6	2	7	5	19	97	3	10	4	11	8	12
O sagittarius	55	6	3	3	1	16	12	3	12	11	9	10
O vanderkelleni	2			1	1	4	23	22	3	7	7	2
O viridulus				5	3	1	2	1				
A lividus	8	901	45	119	105	56	39		2	199	336	82
Aphodius spp2		2	12									
Aphodius spp 10			1							1		
A fimetarius	2			6	3			1			1	
S bicolour	20	12	4	3	2	23	11	19	27	39	26	98
H nomas	1	3	3	12	16	16	5	39	1	17	18	12

NOTE: *for months May, September, October, November only 5 farms had beetles identified.

There were some distinct trends in seasonality for *D gazella* and *L militaris*, with these species being significantly more active and abundant with the onset of the summer storms in October and November and into the wet season (December to February) (Figure 1).

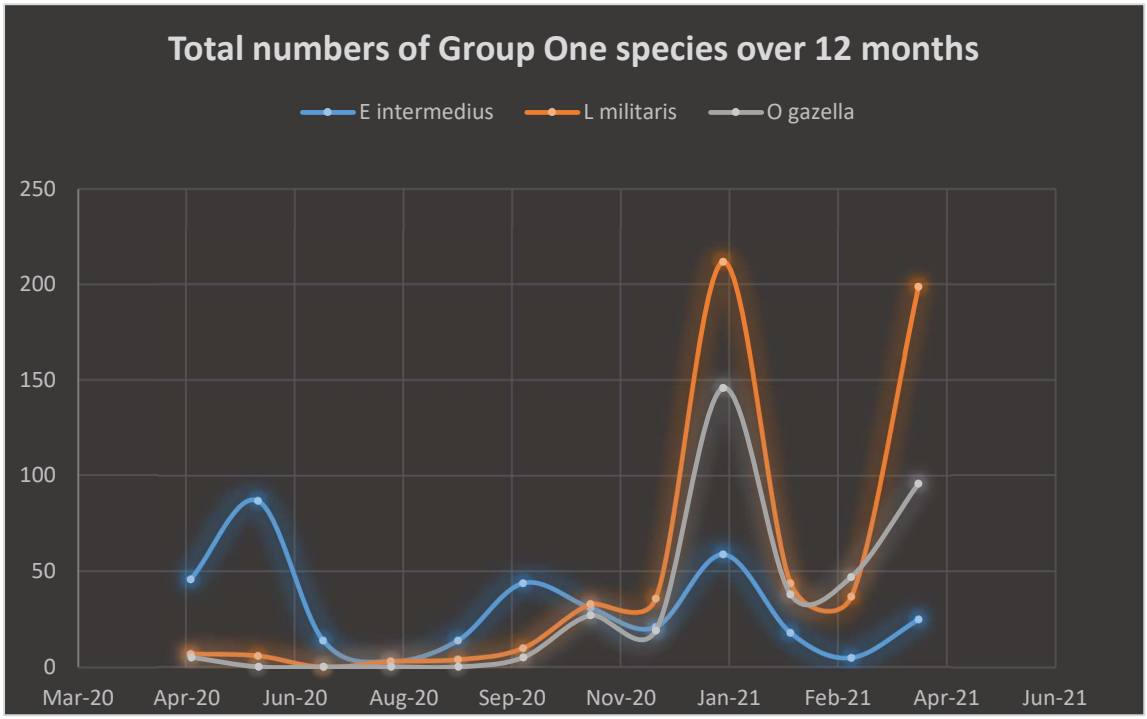


Figure 1: DBID total number of Group One dung beetle species collected from all farms May 2020 – April 2021

O nigriventris was found on five farms; being in relative abundance in the October-November months, however in smaller numbers throughout most other months (Figure 2).

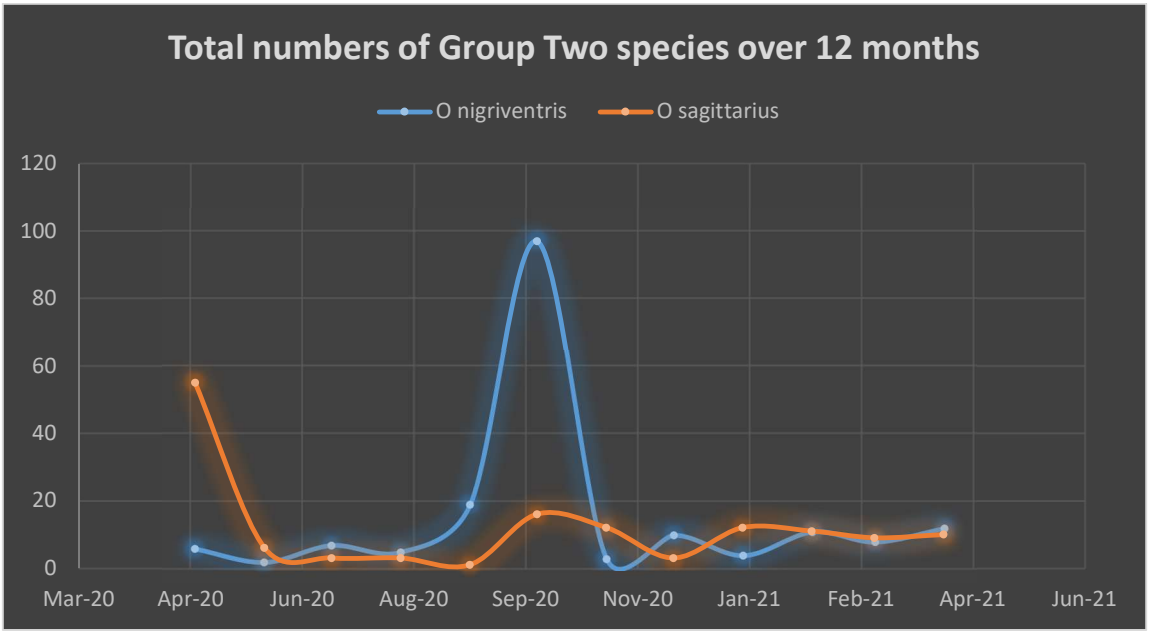


Figure 2: DBID total number of Group Two dung beetle species collected from all farms May 2020 – April 2021

Numbers of both *O vanderkelleni* and *O viridulus* were low over the 12-month collection period but *O vanderkelleni* showed a spike in October- November (Figure 3).

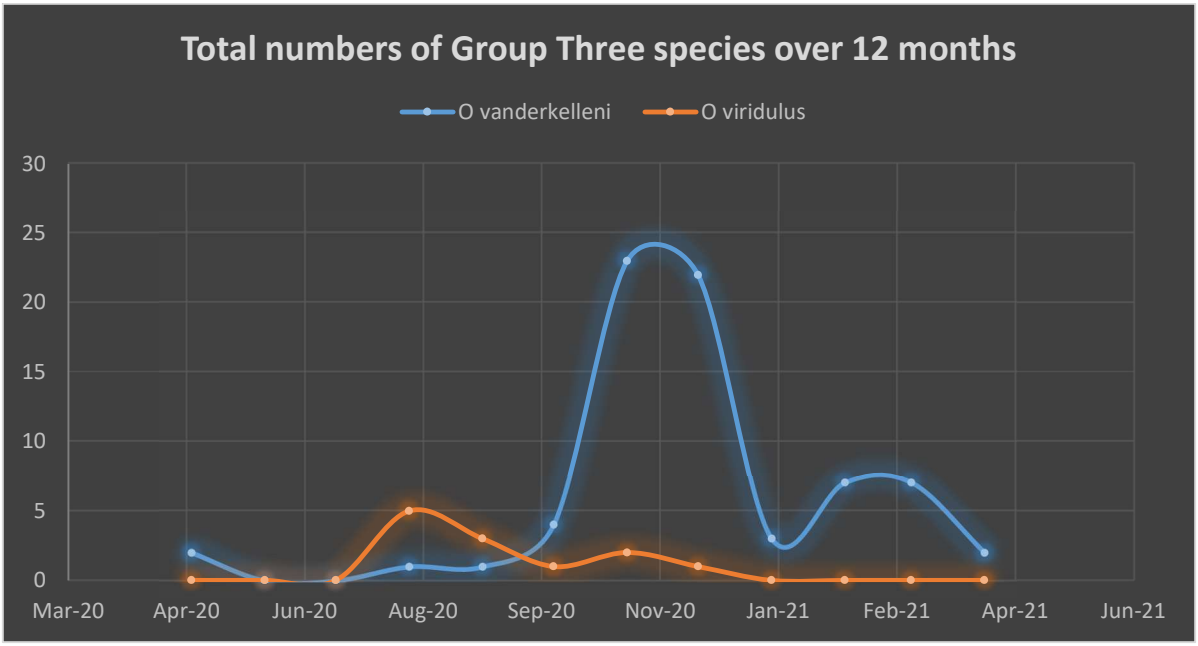


Figure 3: DBID total numbers of Group Three dung beetles collected from all farms May 2020 – April 2021

A lividus was found in relatively large numbers across most farms for some months of the year, peaking with the onset of the summer rains. However, there were some identification and collection issues with this species during the initial months of the project. Some farmers did not collect all these specimens and some did – for example there was a collection of over 880 individuals at one farm in June causing a large spike in the numbers for the 12-month collection period (Figure 4).

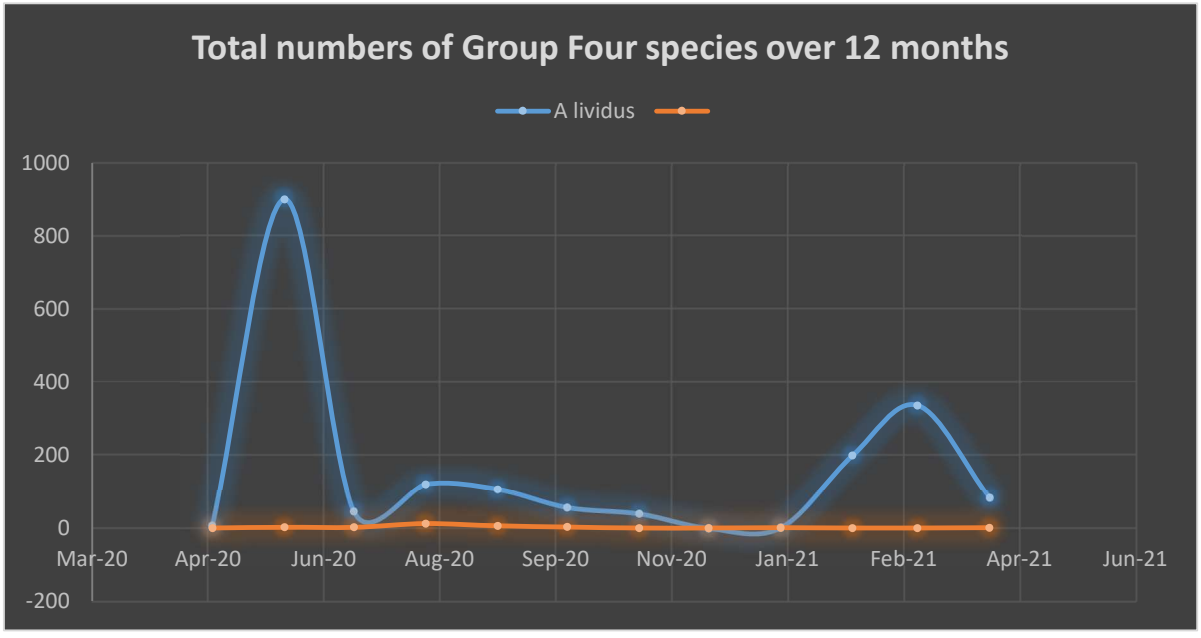


Figure 4: DBID total numbers of Group Four beetles collected from all farms May 2020 – April 2021

Numbers of *S bicolour* and *H nomas* were relatively low overall but both these species were found on the farms at multiple collections (*H nomas* for example, at nine collections at both Farm FTW and Farm PCG) over the 12 collection time points of the DBID project (Table 6). S bicolour showed a spike in numbers toward the end of the wet season (Figure 5).

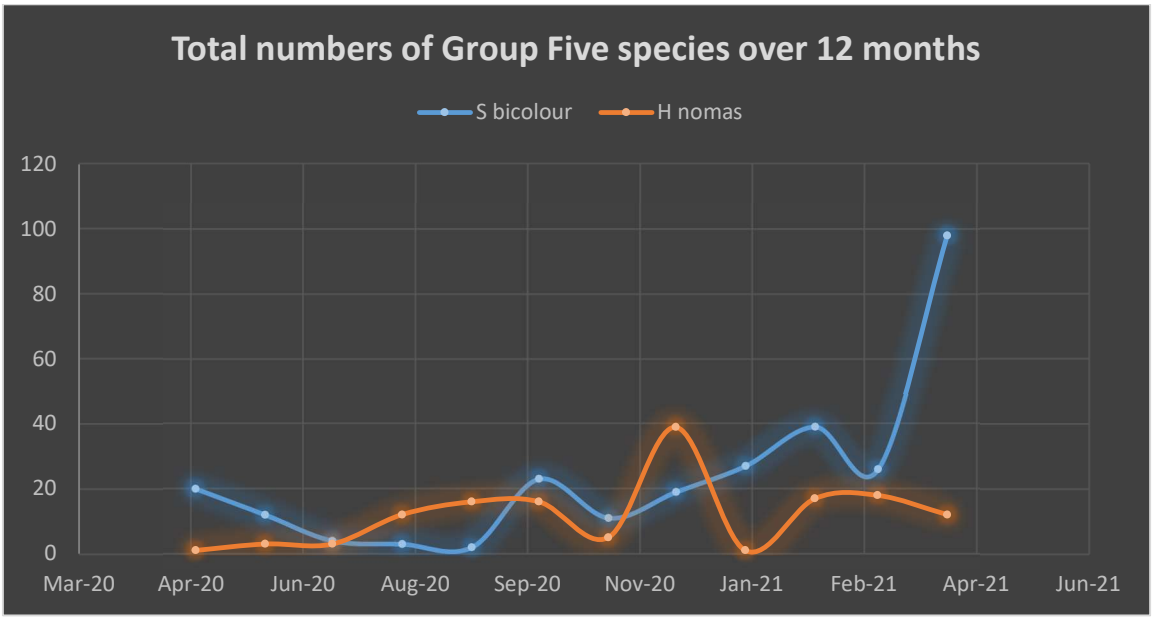


Figure 5: DBID total numbers of Group Five beetles collected from all farms May 2020 – April 2021

Farm Specific Dung Beetle Identification

Each farm had a variety of both introduced and native dung beetle species identified across the 12-month time period. However, there were differences between individual farms in the abundance of each species (Table 8).

Table 8: DBID: Total number of dung beetles found in dung collected from each farm over the 12month collection period

	Platypus Creek	Malanda	FTW	Biodynamic	PCG	Wondecla	TOTAL
E intermedius	0	3	8	13	38	305	**367**
L militaris	2	5	36	28	202	318	**591**
D gazella	7	7	56	46	22	245	**383**
O nigriventris	2	5	0	25	19	133	**184**
O sagittarius	7	3	17	6	21	87	**141**
O vanderkelleni	5	4	2	10	35	16	**72**
O viridulus	0	0	0	4	0	10	**12**
A lividus	26	66	1242	39	202	317	**1892**
A spp2	0	0	14	0	0	0	**14**
A spp10	0	1	0	0	1	0	**2**
A fimetarius	0	0	9	0	2	2	**13**
H nomas	18	21	11	21	49	23	**143**
S bicolour	58	47	9	63	73	34	**284**
TOTAL	**125**	**162**	**1404**	**253**	**664**	**1490**	**4098**

Farm Wondecla had the most variety and abundance of dung beetles over the 12-month collection period (Table 8) compared to the other farms. However, *H nomas* and *S bicolour* were less abundant at this farm compared to some of the other farms (Table 8). Dung beetles had been previously identified on this farm (Table 2) prior to the introduction of additional dung beetle colonies in 2014 and 2016. One colony each of *E intermedius* and *D gazella* were introduced during the 2016 MBPG Project and numbers of these species were found in greater abundance on this farm compared to the other farms in the DBID project. However, there were seven other species introduced in either 2014 or 2016 (Table 2), that were not identified at any time during the DBID Project*: O binodus, O taurus, O fulvus, O alexis, africanus, S rubrus* and *S spinipes*. This may be due to the low number of individuals released not being enough to support establishment of the species at this property.

O nigriventris was collected in most months in small numbers (Table 9), at Farm Wondecla, but was abundant and active over October-November in both cattle and horse manure[15]. There was a distinct rise in dung beetle activity with the onset of the summer rains in December especially with greater numbers of *D gazella* and *L militaris* (Figure 6). The abundance of *A lividus* is under reported at this farm due to the challenges of collecting this small beetle and the owner not collecting every individual when the numbers were large (over 100 per dung pad in February and March).

[15] Gail Abernethy Personal correspondence

Farm Wondecla found more species of native dung beetles than any other of the farms. This may be due to the number of regular kangaroo visitors to the paddocks.

Table 9: DBID Project: Farm Wondecla monthly identification and abundance May 2020 – April 2021

Wondecla	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	Apr
E intermedius	44	82	11	2	14	44	31	14	35	2	3	23
L militaris	6	3			1	10	30	12	207	19	27	3
D gazella	2					1	21	4	137	23	24	33
O nigriventris	5	1	1	1	15	92	3		2	1	2	10
O saggitarus	50	4	2	2		12	11		1		3	2
O vanderkelleni				1	1	1	8	1	3		1	
O viridulus				3	1	1	4	1				
A lividus			3	28	60	26	5			160	30	5
A fimetarius	2											
S bicolour	1	7	1			7	5	1		1	6	6
H nomas					1	9	4	8	1			

Figure 6 displays the peaks in abundance of Group One dung beetles across the 12 month collection period at Farm Wondecla. E intermedius peaked in June while the other two Group One species peaked with the onset of the summer rain.

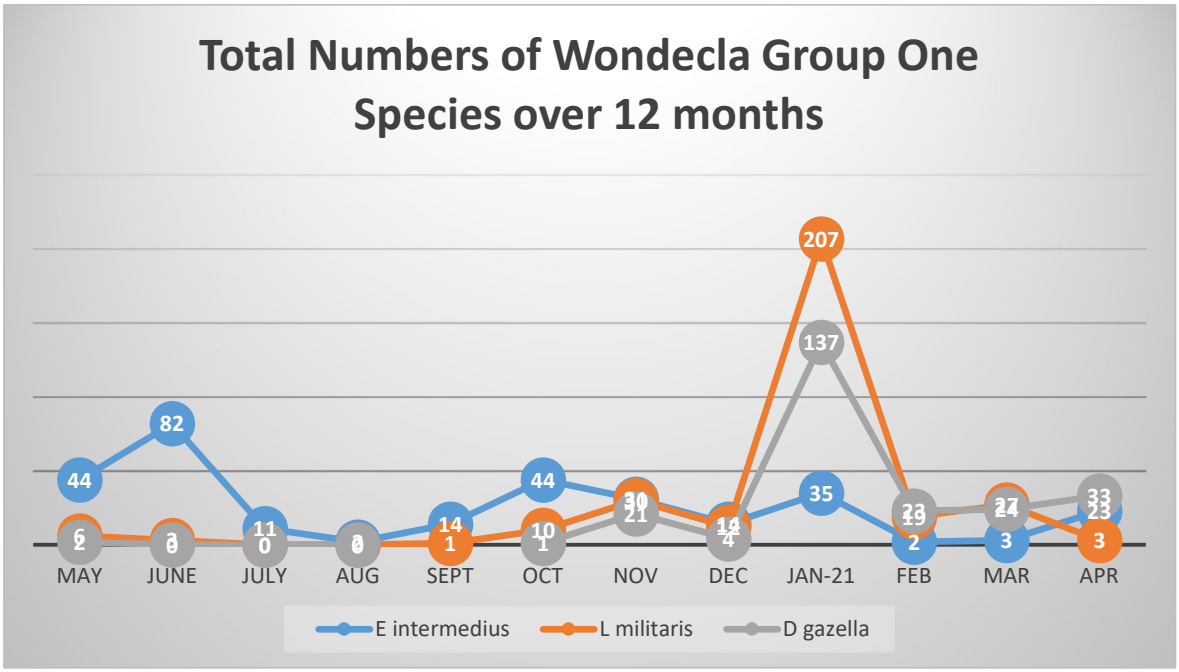


Figure 6: DBID total number of Group One dung beetle species collected from Wondecla May 2020 – April 2021

Figure 7 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Farm Wondecla. *O nigriventris* peaked in October, while *O saggitarus* numbers were low overall with a smaller peak in May.

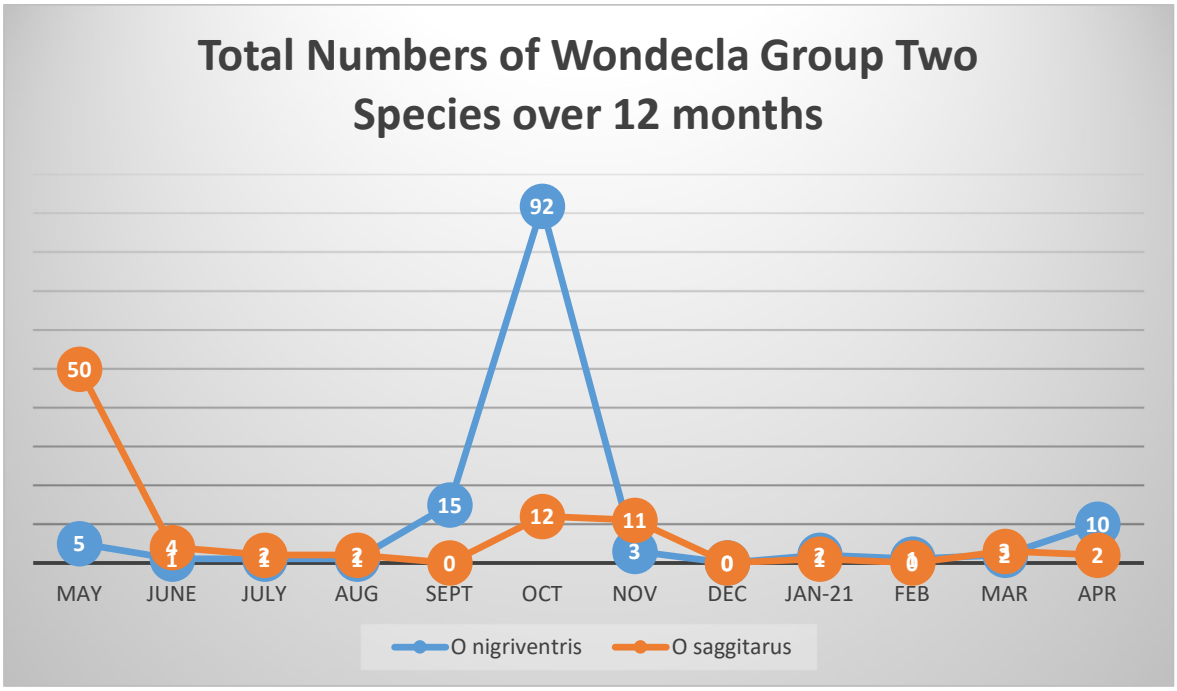


Figure 7: DBID total number of Group Two dung beetle species collected from Wondecla May 2020 – April 2021

Figure 8 displays the peaks in abundance of Group Three dung beetles across the 12 month collection period at Farm Wondecla. Numbers were extremely small for these species. There were no more that 8 indviduals collected per month for these species and most beetles were collected in November.

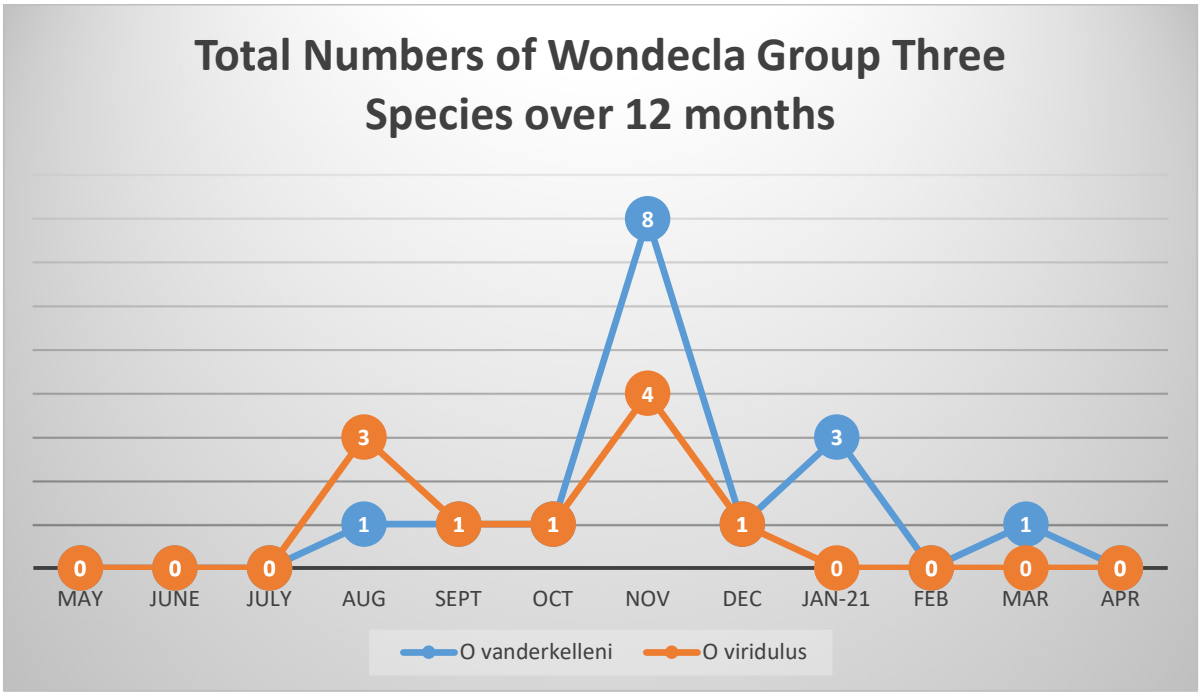


Figure 8: DBID total numbers of Group Three dung beetles collected from Wondecla May 2020 – April 2021

Numbers of *A lividus* appeared to have two peaks during the year: September and February at Wondecla, however numbers of this species are likely to be underreported during these times. There was only one collection over the 12-month collection period (two individual beetles) of *A fimetarius* in May (Figure 9).

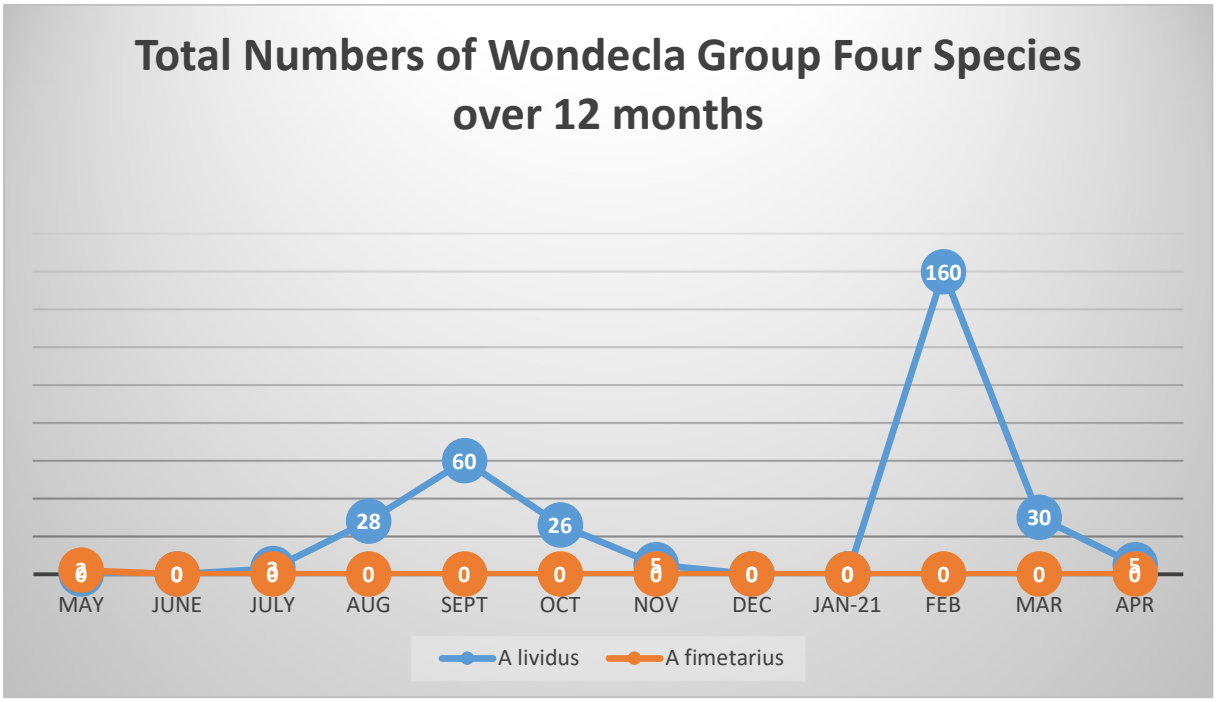


Figure 9: DBID total numbers of Group Four dung beetles collected from Wondecla May 2020 – April 2021

Figure 10 displays the peaks in abundance of Group Five dung beetles across the 12 month collection period at Farm Wondecla. Numbers were very small for these species. There were no more that nine indviduals collected per month for these with the most beetles collected in October.

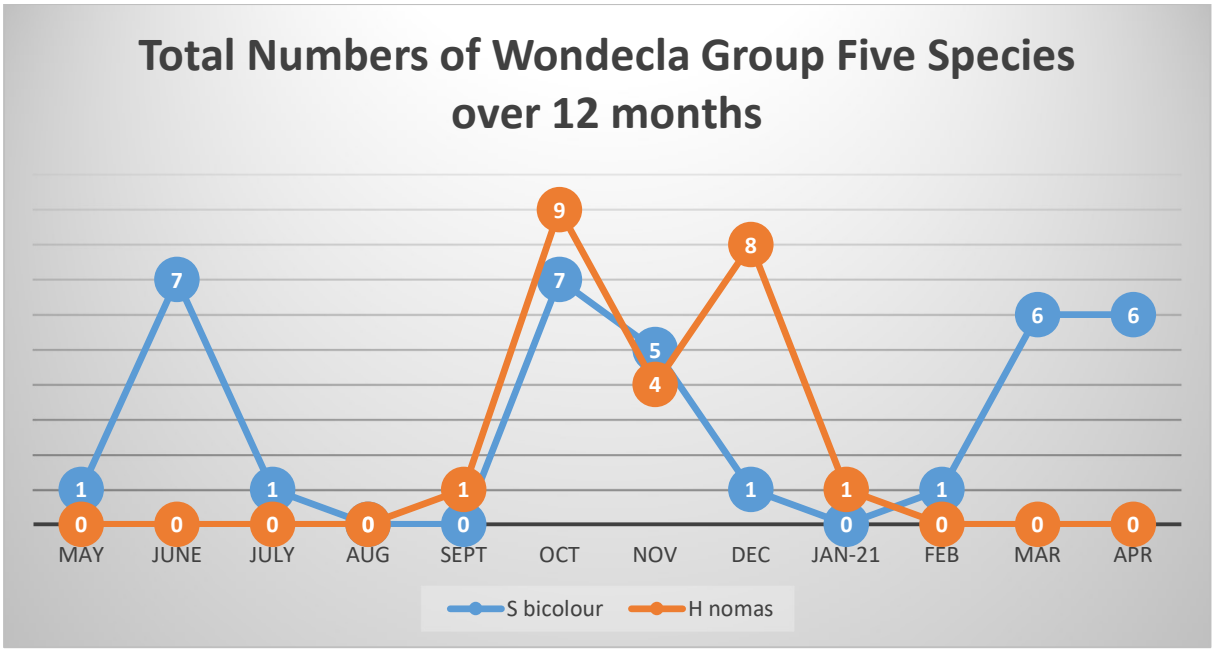


Figure 10: DBID total numbers of Group Five dung beetles collected from Wondecla May 2020 – April 2021

Farm PCG collected a variety of species but overall numbers were low, with two notable exceptions (Table 9). *O vanderkelleni* was active on this property from October to December with a peak of 20 specimens collected in December – the highest number of this species collected at any one time from any farm. The owners of Farm PCG introduced two species of dung beetle colonies during the MBPG Project in 2016 (*D gazella, O alexis*), however, *O alexis* was not identified at any time during the DBID Project. A species found on other DBID farms (O viridulus) was not collected from Farm PCG. There were three species of native dung beetle collected. The property has stands of native trees on the property and established rainforest around the creek providing shade for the livestock, however the owners report rarely seeing any marsupials on the property.

Table 9: DBID Project: Farm PCG monthly identification and abundance May 2020 – April 2021

Farm PCG	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	Apr
E intermedius	1		3	1				5	24	4		
L militaris										6	5	191
D gazella	3							7	1		3	8
O nigriventris	1	1	2	4	3			5	2	1		
O saggitarus	1		1				1	2	7	5	3	1
O vanderkelleni	1					2	8	20		3	1	
A lividus		2	9	6	18	7	15			9	85	51
Aphodius spp 10 tiny			1									
A fimetarius				1							1	
S bicolour	2	2	1		1	3			1	18	1	44
H nomas	1	1	1	2	1	5		16		12	6	4

Figure 11 displays the peaks in abundance of Group One dung beetles across the 12 month collection period at Farm PCG. The peak in abundance of *L militaris* was in April, and in January for the *E intermedius* across the 12 month collection period. There were 191 specimens of *L militaris* collected in April (Figure 8). This was the second highest collection of all the farms during the year of this species (the other being Farm Wondecla in January).

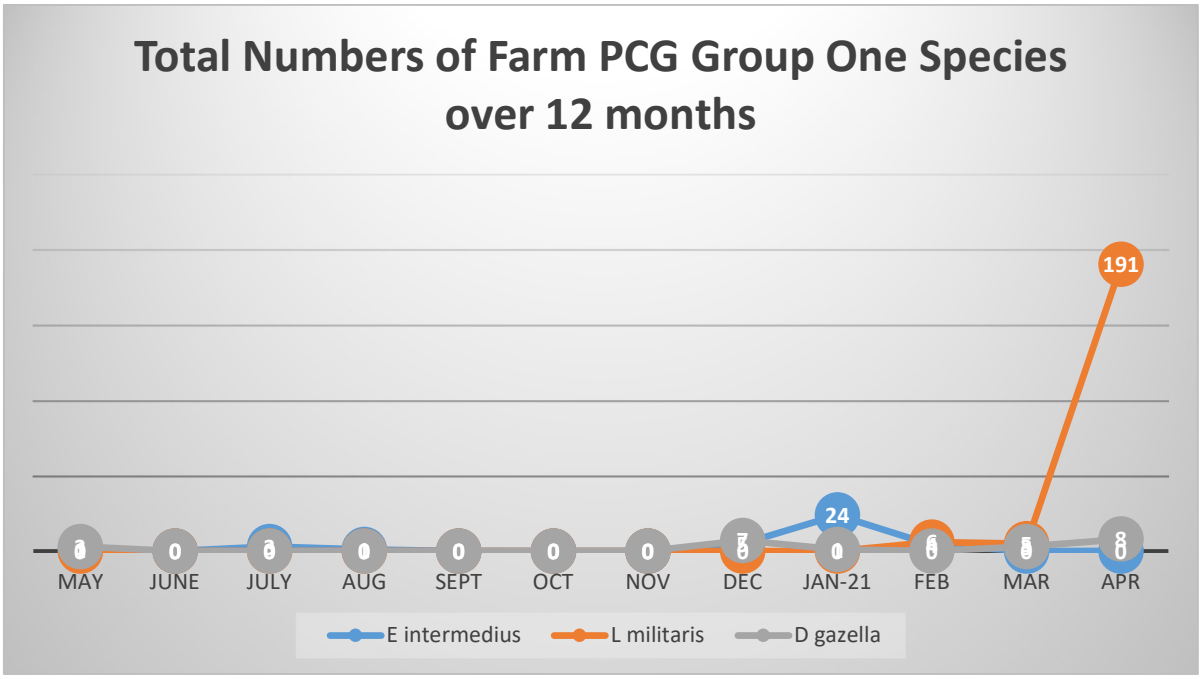


Figure 11: DBID total number of Group One dung beetle species collected from Farm PCG May 2020 – April 2021

Figure 12 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Farm PCG. While numbers were very low, specimens of the *O nigriventris* were collected from this farm over most months of the year, with peaks in abundance in August and December. The peak number collected of the O saggitarus was in January.

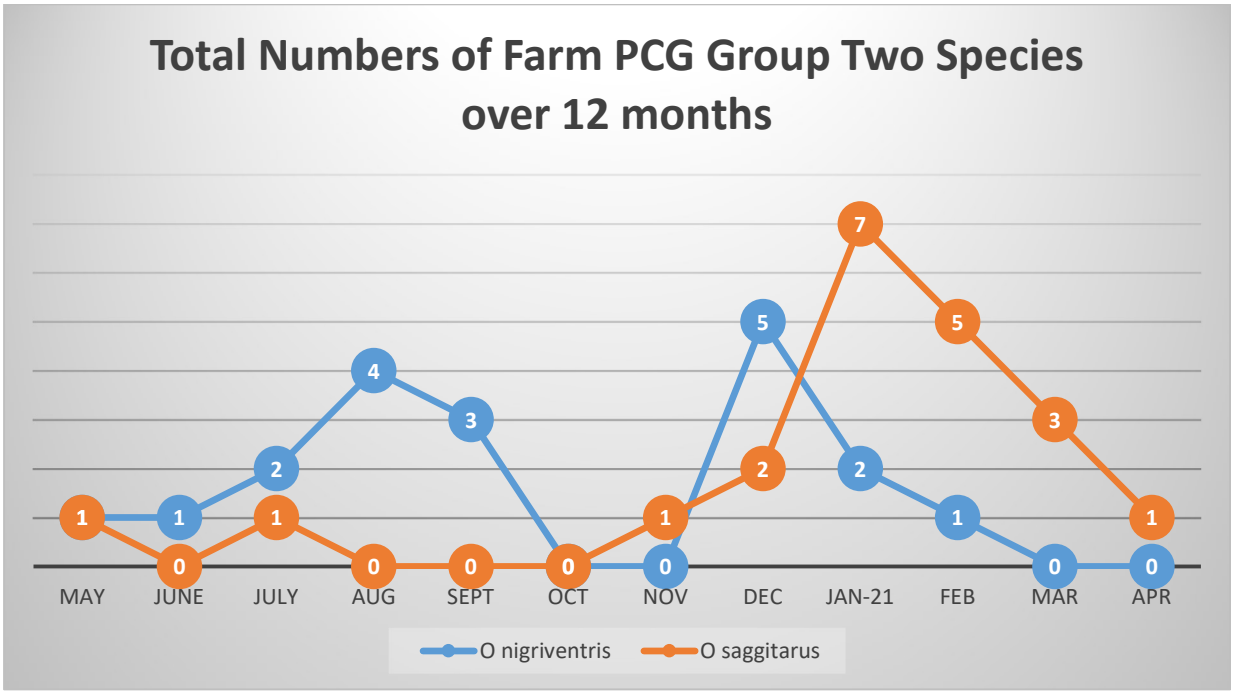


Figure 12: DBID total number of Group Two dung beetle species collected from Farm PCG May 2020 – April 2021

Figure 13 displays the peaks in abundance of Group Three dung beetle species collected across the 12 month period at Farm PCG. There was only one species of this Group collected: O vanderkelleni and numbers peaked in December.

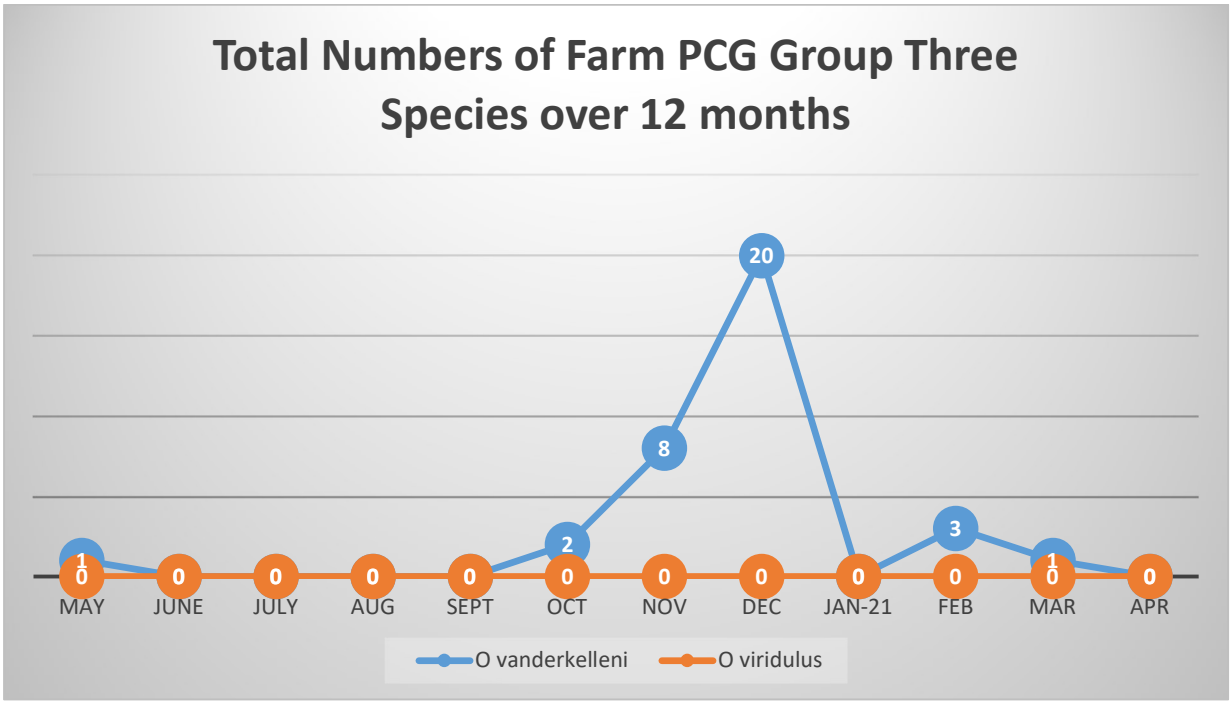


Figure 13: DBID total numbers of Group Three dung beetles collected from Farm PCG May 2020 – April 2021

Numbers of *A lividus* appeared to have one peak during the year at this farm, over the March-April collection time points. *A lividus* was identified at nine collection points over the 12-month time period (Figure 14).

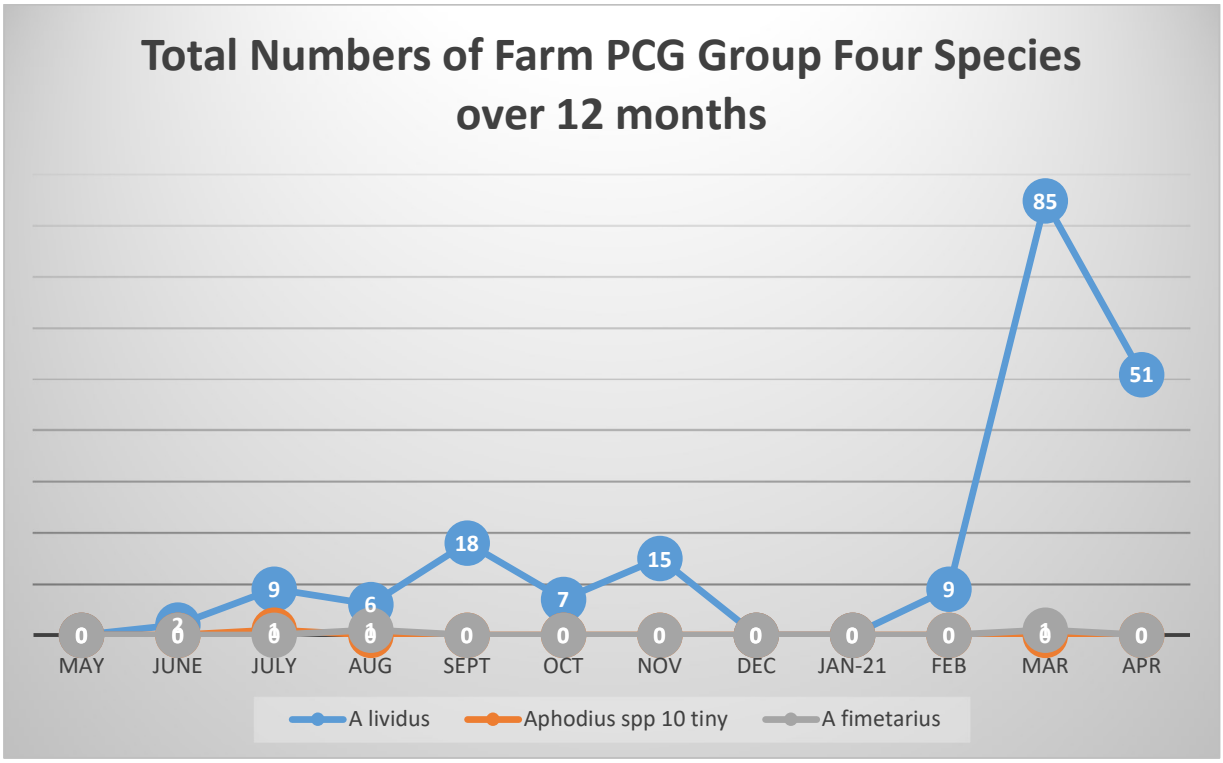


Figure 14: DBID total numbers of Group Four dung beetles collected from Farm PCG May 2020 – April 2021

Figure 15 displays the peaks in abundance of Group Five dung beetles across the 12 month collection period at Farm PCG. A small number of sspecimens of the *H nomas* and *S bicolour* were collected from this farm over most months of the year. *S bicolour* peaked in February and April and *H nomas* in December and February.

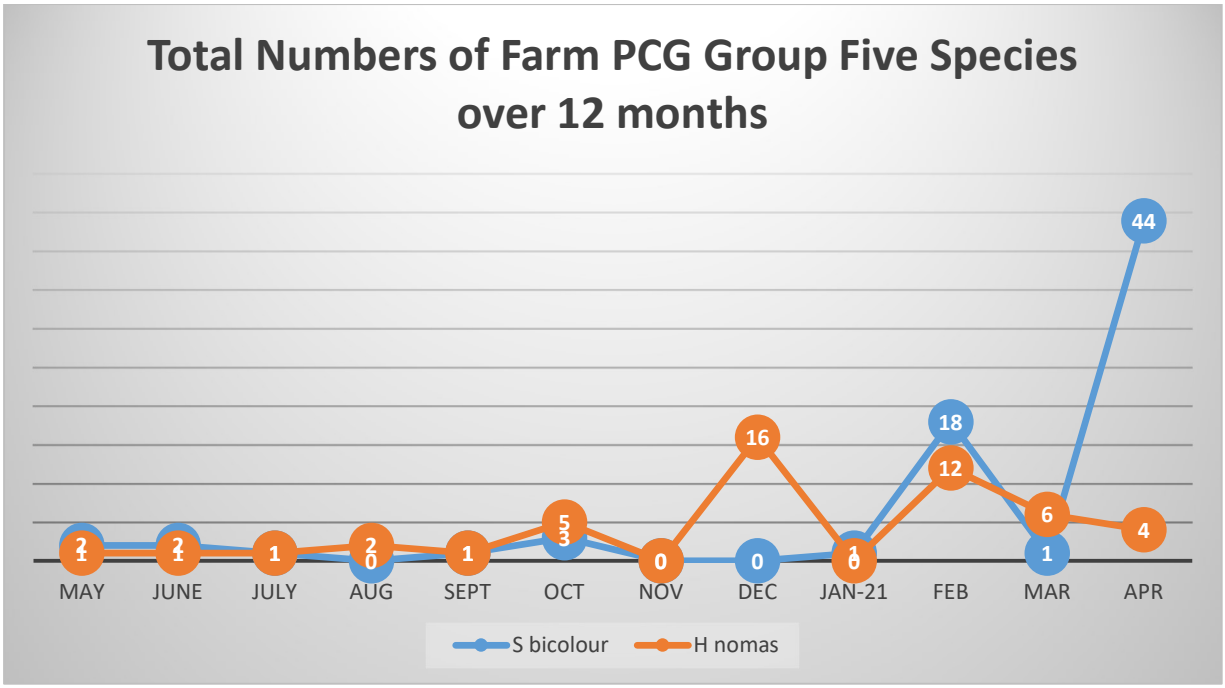


Figure 15: DBID total numbers of Group Five dung beetles collected from Farm PCG May 2020 – April 2021

Farm Malanda collected a variety of species but in very small numbers throughout the 12-month collection period. Unfortunately, the collection from September was not received by Dr Doube by post for identification. The most abundant and frequently collected beetles were the *H nomas, S bicolour* and *A lividus* species. The *A lividus* numbers may be underreported from this farm for the first few months as the farmer was unsure as to whether they should be collecting all of the individuals.

Table 10: DBID Project: Farm Malanda monthly identification and abundance May 2020 – April 2021

Dairy Malanda	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	Apr
E intermedius		3										
L militaris	1	1					1		1		1	
D gazella							6	1				
O nigriventris										5		
O saggitarus									1	2		
O vanderkelleni							2			1	1	
A lividus		5				11	15			15	10	10
Aphodius spp 10 tiny										1		
S bicolour	3		2	1		3		9	16	1	11	1
H nomas			1	1		1		15		2		1

Figure 16 displays the peaks in abundance of Group One, Two and Three species across the 12 month collection period at Farm Malanda. There was a peak in abundance of *O nigreventris* (February) and *D gazella* (November) species across the 12 month collection period at Farm Malanda, however, total numbers collected each month were extremely small. There were no collections at anytime of O viridulus or here were no instances of more than six individual specimens for any dung beetle species collected at any of the collection time points.

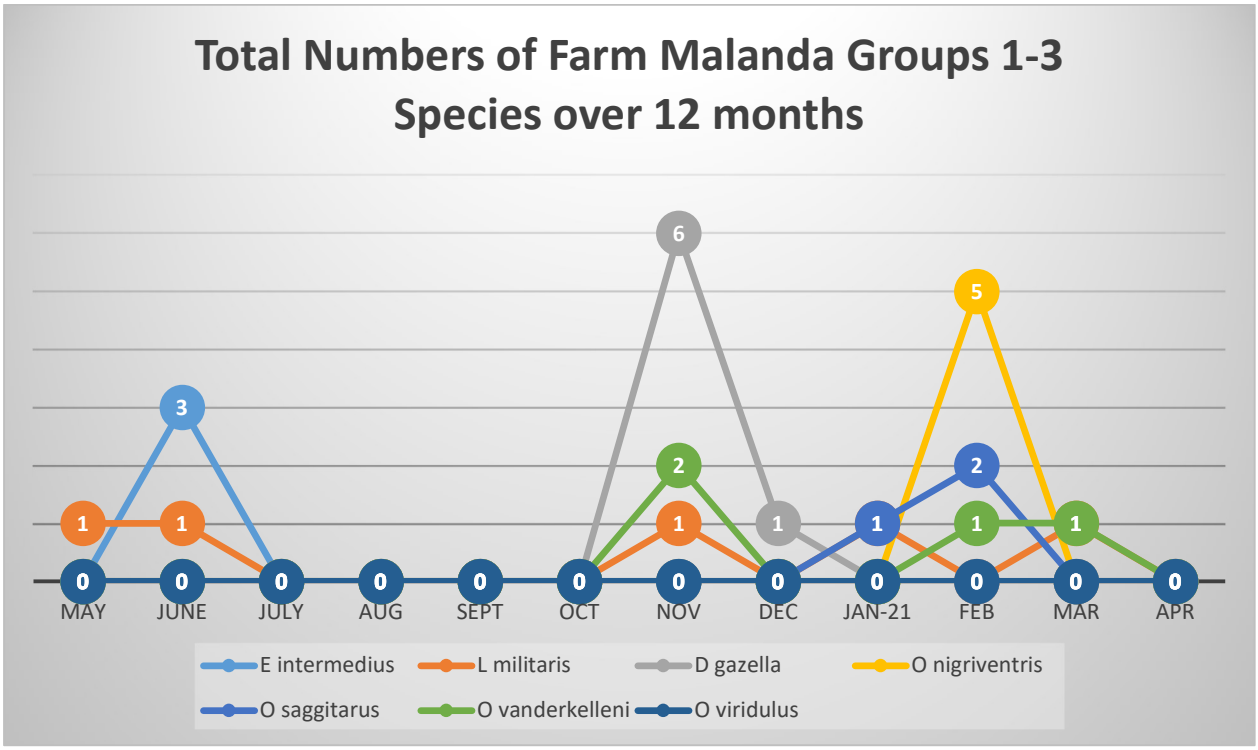


Figure 16: DBID total number of Group One, Two and Three dung beetle species collected from Farm Malanda May 2020 – April 2021

Numbers of *A lividus* appeared to peak in November and February but as discussed above, not all specimens were collected throughout the 12-month period (Figure 17). There were no specimens of *A fimetarius* collected from this farm.

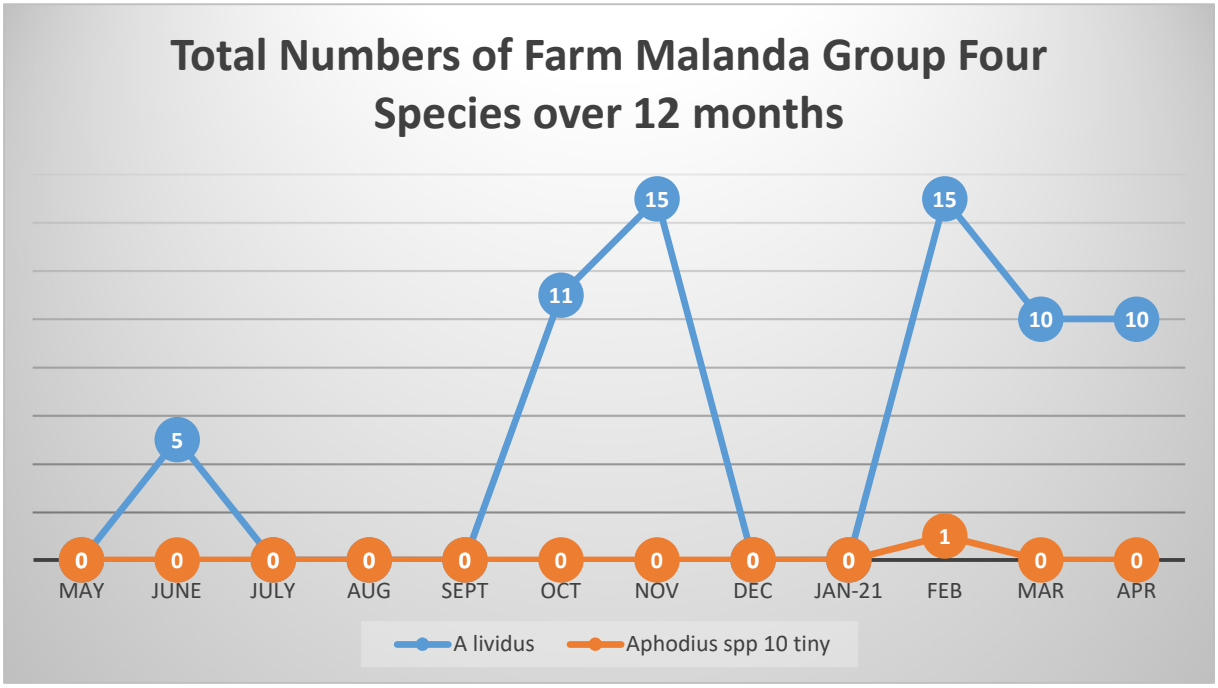


Figure 17: DBID total numbers of Group Four dung beetles collected from Farm Malanda May 2020 – April 2021

Figure 18 displays the peaks in abundance of Group Five dung beetles across the 12 month collection period at Farm Malanda. *S bicolour* had a double peak in January and March while *H nomas* peaked in December.

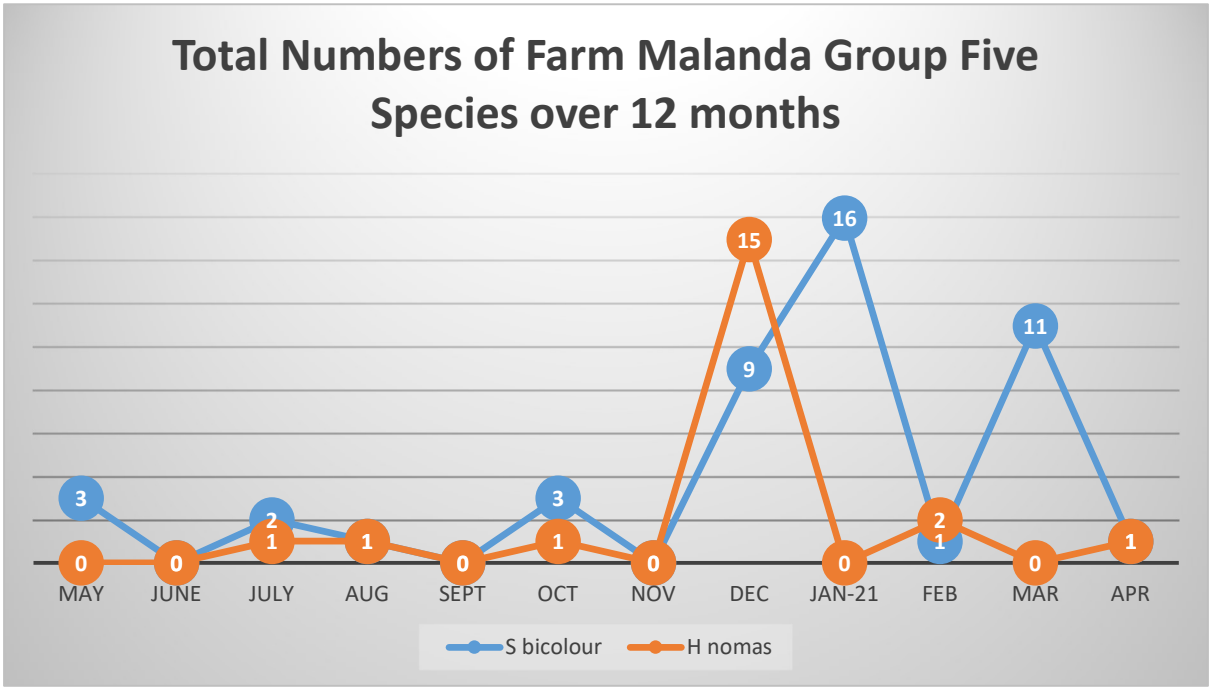


Figure 18: DBID total numbers of Group Five dung beetles collected from Farm Malanda May 2020 – April 2021

The most abundant and frequently collected beetle at **Farm FTW** was the *A lividus* with over 880 collected in June (Table 11). Numbers for this beetle are under reported at this farm during May as there were more individuals in the collection but not sent for identification. There were three species of native dung beetle collected in very small numbers (maximum of two beetles per species) during November and December at this farm.

The *O nigriventris* was not collected at any time during the 12-month time period but was collected at least once on every other farm.

Table 11: DBID Project: Farm FTW monthly identification and abundance May 2020 – April 2021

Farm FTW	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	Apr
E intermedius	1							1		2	2	2
L militaris		2		3	3			19	3		3	3
D gazella								3	4	1	5	43
O saggitarus	3	1		1				1	3	2	3	3
O vanderkelleni							1			1		
A lividus	8	887	33	85	17	5	4				196	7
Aphodius spp2 bull head		2	12									
A fimetarius				5	3			1				
S bicolour					1				8			
H nomas		1		6	2					2		

Figure 19 displays the peaks in abundance of Group One dung beetles across the 12 month collection period at Farm FTW. There was a rise in numbers of the *L militaris* (19 individuals) with the onset of the summer rains but not sustained over the following months. The *D gazella* species was collected in very small numbers (less than 6 individuals) from December with a peak of 43 individuals collected in April. E intermedius was collected in very small numbers in the wet season.

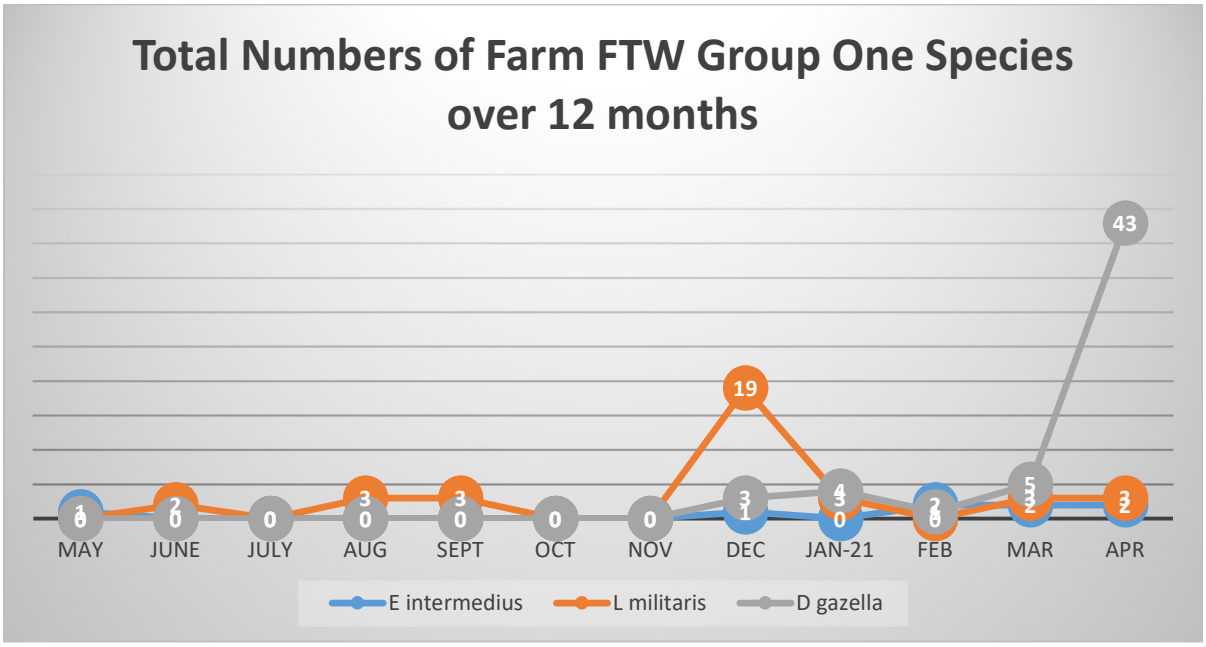


Figure 19: DBID total number of Group One dung beetle species collected from Farm FTW May 2020 – April 2021

Figure 20 displays the peaks in abundance of Group Two and Three dung beetles across the 12 month collection period at Farm FTW. *O saggitarius* was identified in eight collections (but in extremely small numbers) over the 12-month time period. There was one specimen of *O vanderkelleni* collected in November and February. There were no *O nigrventris* or *O viridulus* specimens collected from this farm at anytime over the 12 month period.

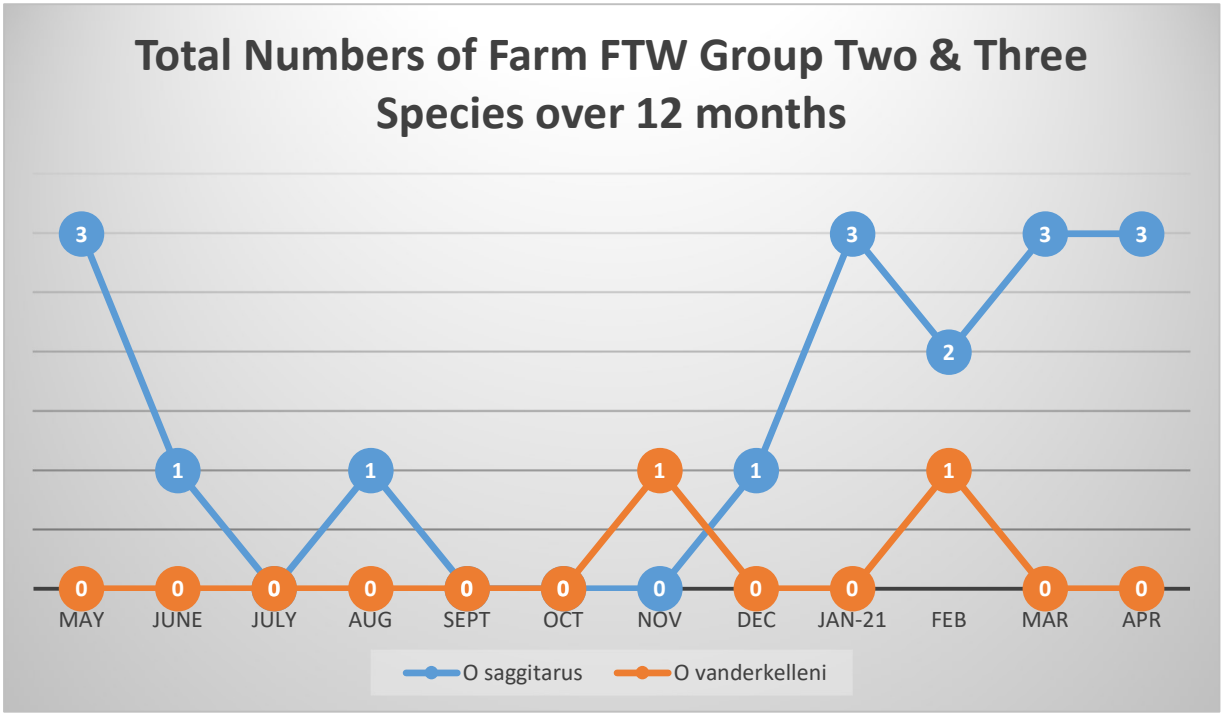


Figure 20: DBID total number of Group Two and Three dung beetle species collected from Farm FTW May 2020 – April 2021

A large number of *A lividus* (Figure 21) were collected at this farm in the June collection. However, there were no individuals of *A lividus* found from December to February but they were back in numbers in the March collection. There was another species of Aphodius identified in June and July (Aphodius spp2 bull head).

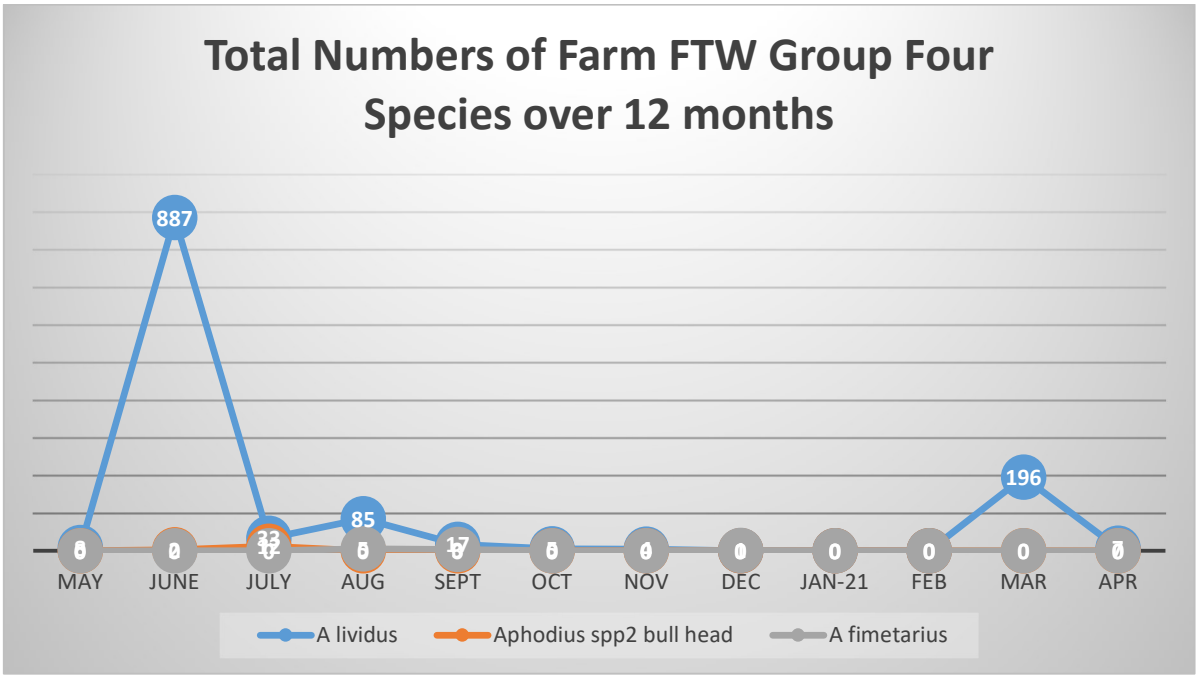


Figure 21: DBID total numbers of Group Four dung beetles collected from Farm FTW May 2020 – April 2021

Figure 22 displays the two collections (September and January) of the *S bicolour* from this farm, and the four collections of the *H nomas* over the 12-month time period; both species in very low numbers.

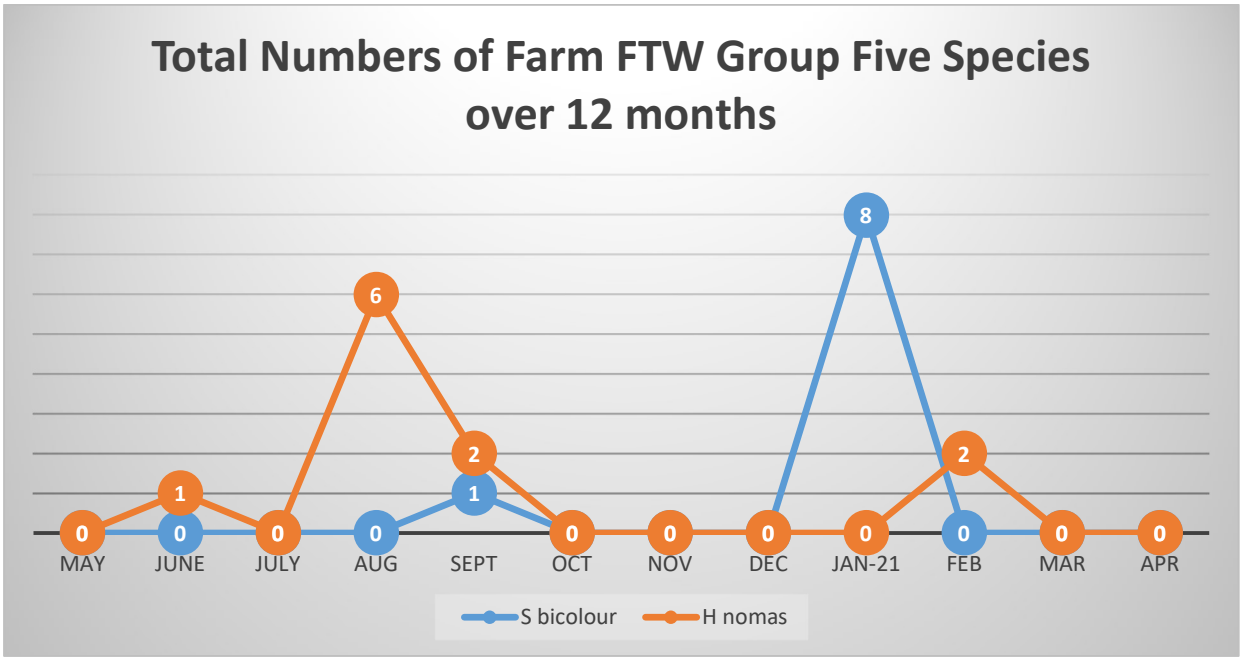


Figure 22: DBID total numbers of Group Five dung beetles collected from Farm FTW May 2020 – April 2021

Five of the DBID Farmers comparing notes (missing from photo Farm Malanda)

Farm Biodynamic collected 10 different species of dung beetle, however numbers generally were low of all identified species throughout the year (less than 20 individuals for all species) (Table 12). There were five different species of native dung beetle collected at this farm during the 12-month collection period, however only one individual specimen of each species was found.

Table 12: DBID Project: Farm Biodynamic monthly identification and abundance May 2020 – April 2021

Biodynamic	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	Apr
E intermedius		2						1		10		
L militaris							2	5	1	17	1	2
D gazella						4		4		14	15	9
O nigriventris			4			5		5		3	6	2
O saggitarus						4						2
O vanderkelleni						1	4	1			4	
O viridulus				2	2							
A lividus		7				7			2	10	10	3
S bicolour		1	1			10	6	4	2	17	6	16
H nomas			1	2	1	1	1			1	7	7

Despite the introduction of dung beetle colonies in the MBPG Project in 2016 (*E intermedius* and *D gazella*), the abundance of these two species was low and the *E intermedius* was only collected at three time points with a maximum of 10 individuals collected in February. There were no *D gazella* collected from May to September and then a rise in abundance (to a maximum of 15 individuals) in the February to April rainy season (Figure 23).

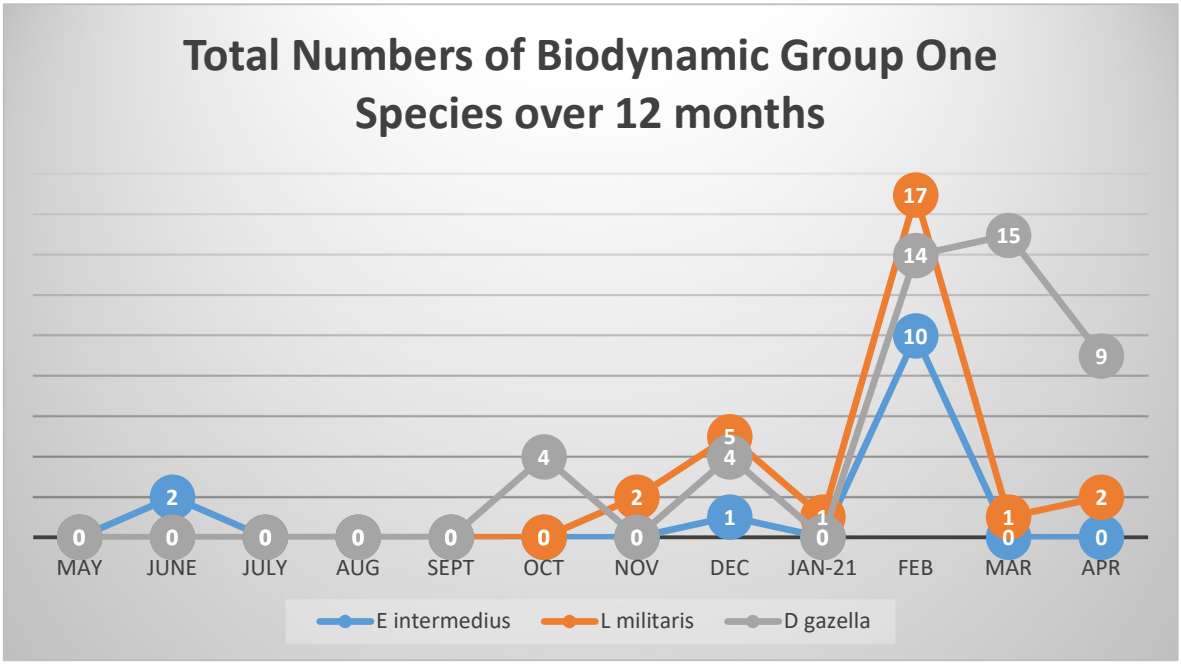


Figure 23: DBID total number of Group One dung beetle species collected from Biodynamic May 2020 – April 2021

Figure 24 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Biodynamic. Numbers of these species were extremely low, however O nigriventris had three spikes in collection numbers (Octber, December and March).

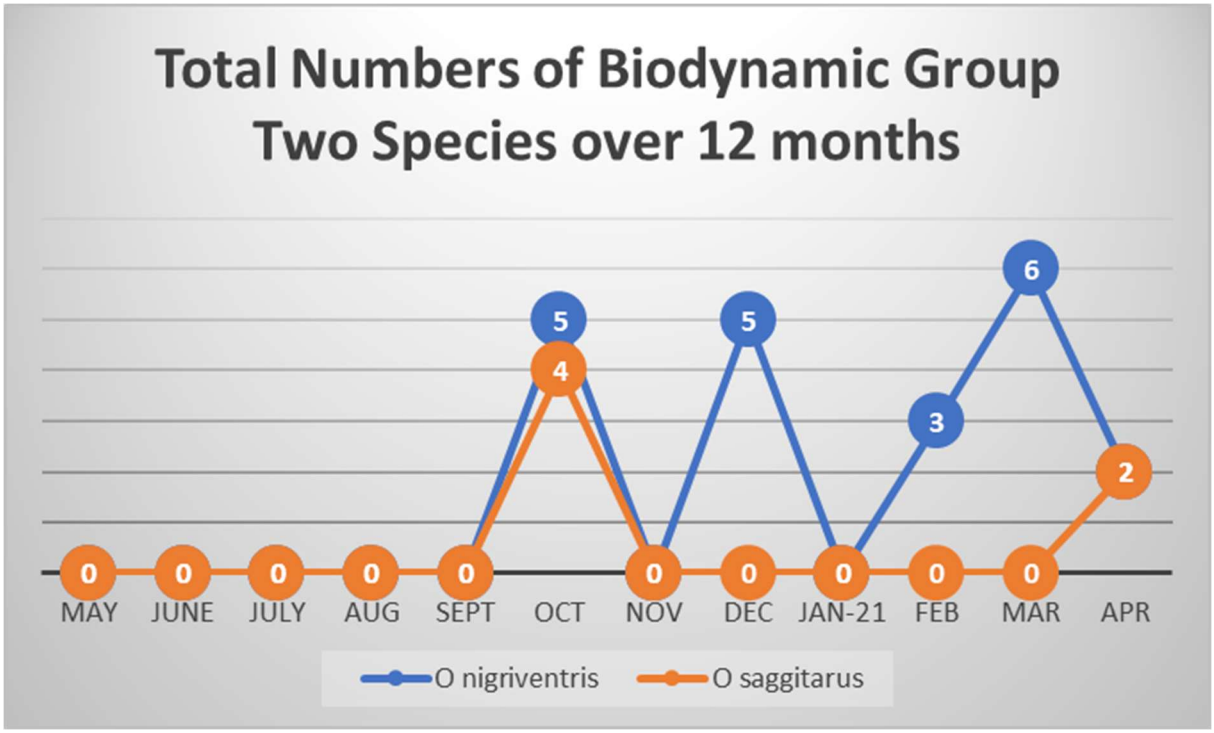


Figure 24: DBID total number of Group Two dung beetle species collected from Biodynamic May 2020 – April 2021

Figure 25 displays the peaks in abundance of Group Three dung beetle species collected across the 12 month period at Biodynamic. Numbers of these species were extremely low with O vanderkelleni peaking in November and March.

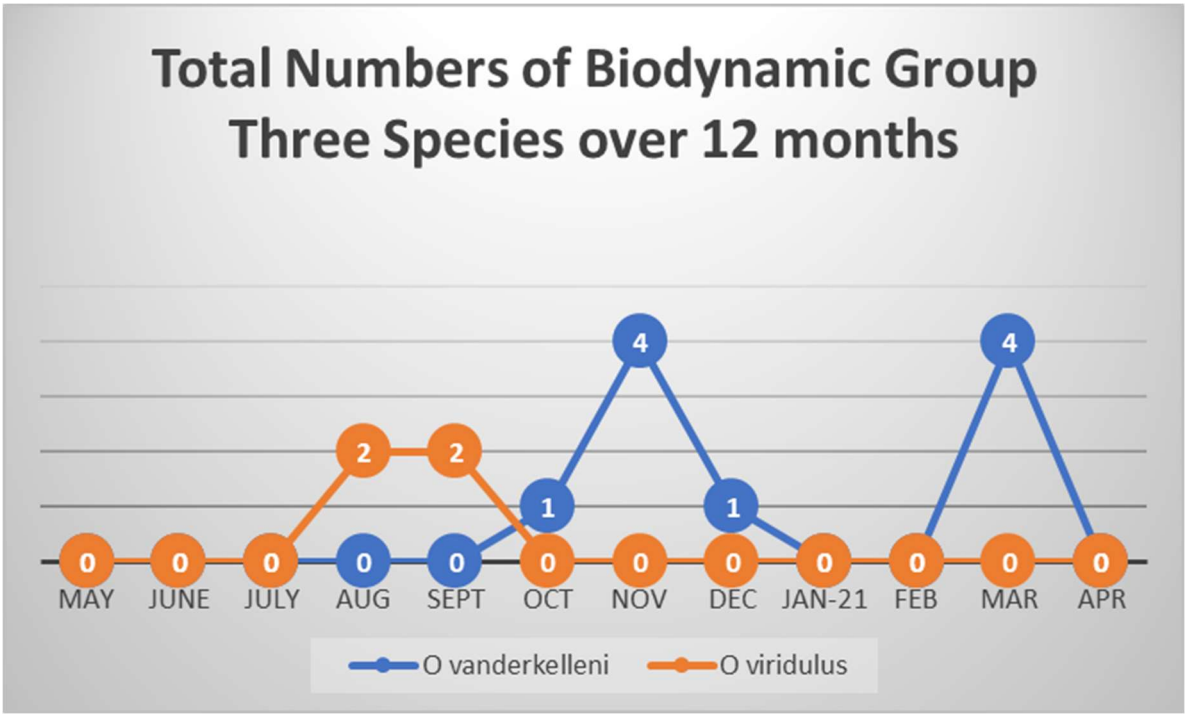


Figure 25: DBID total numbers of Group Three dung beetles collected from Biodynamic May 2020 – April 2021

Figure 27 displays the peaks in abundance of Group Four and Five dung beetles across the 12 month collection period at Biodynamic. Again, numbers of these species were small. The *A lividus* was most active in the rainy season (January to March), but individuals of this species were collected in June and October. Both *S bicolour* and *H nomas* were collected at multiple time points across the 12-month period (nine and eight respectively). Peak abundance for *S bicolour* was in February and April, but in low numbers (less than 20 individuals in any one collection).

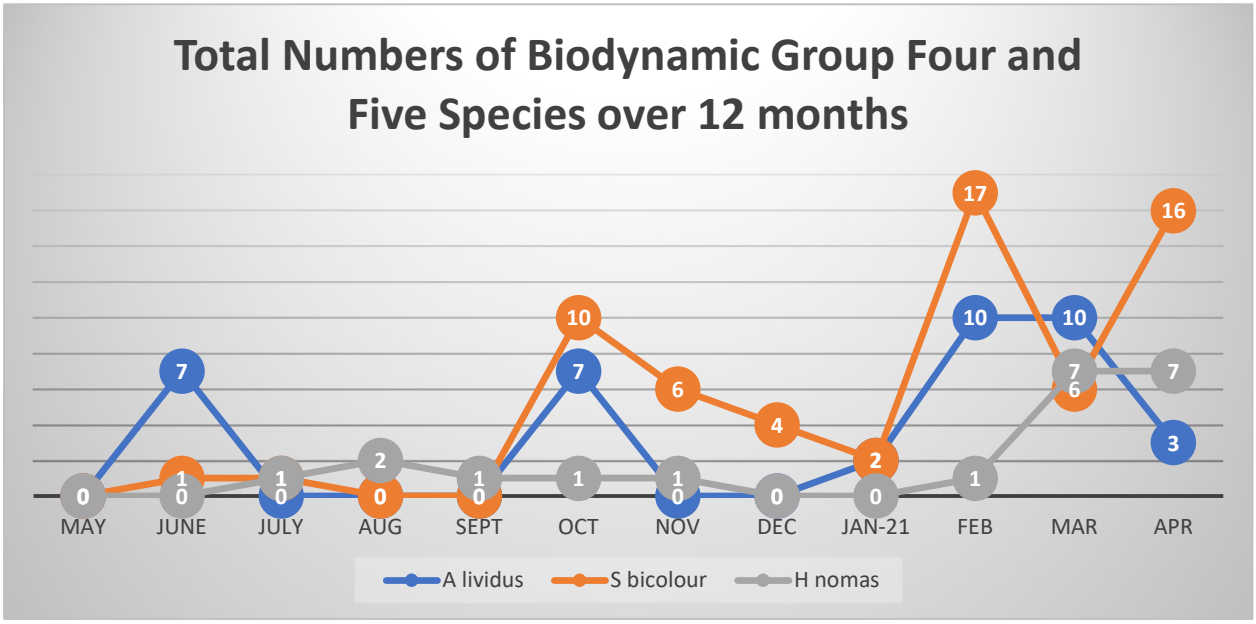


Figure 26: DBID total numbers of Group Four and Five dung beetles collected from Farm PCG May 2020 – April 2021

Farm Platypus Creek collected eight separate species; however, numbers generally were very low of all identified species throughout the year (less than 15 individuals for all species except for one instance) (Table 13), and no beetles at all were found July. Unfortunately, Australia Post lost two months of collections (October and November) so there may be both introduced and native species on this farm not yet identified.

There were no collections at any time of *O viridulus* at this property. *E intermedius* was identified at least once at each of the other farms but was not found at this farm during the timeframe of the DBID project. However, this beetle was identified by Dr Doube from this farm in June 2021 as part of another project.

There were two native species identified at this farm over the 12-month time period (Table 5).

Table 13: DBID Project: Farm Platypus Creek monthly identification and abundance May 2020 – April 2021

Platypus Creek	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-21	Feb	Mar	April
D gazella									4			3
O nigriventris					1					1		
L militaris										2		
O saggitarus	1	1			1					2		2
O vanderkelleni	1									2		2
A lividus					10					5	5	6
S bicolour	14	2		2				5		2	2	31
H nomas		1		1	11						5	

Figure 28 displays the peaks in abundance of Group One, Two and Three species of dung beetles across the 12 month collection period at Platypus Creek. Numbers of these species were very low across the 12 month period.

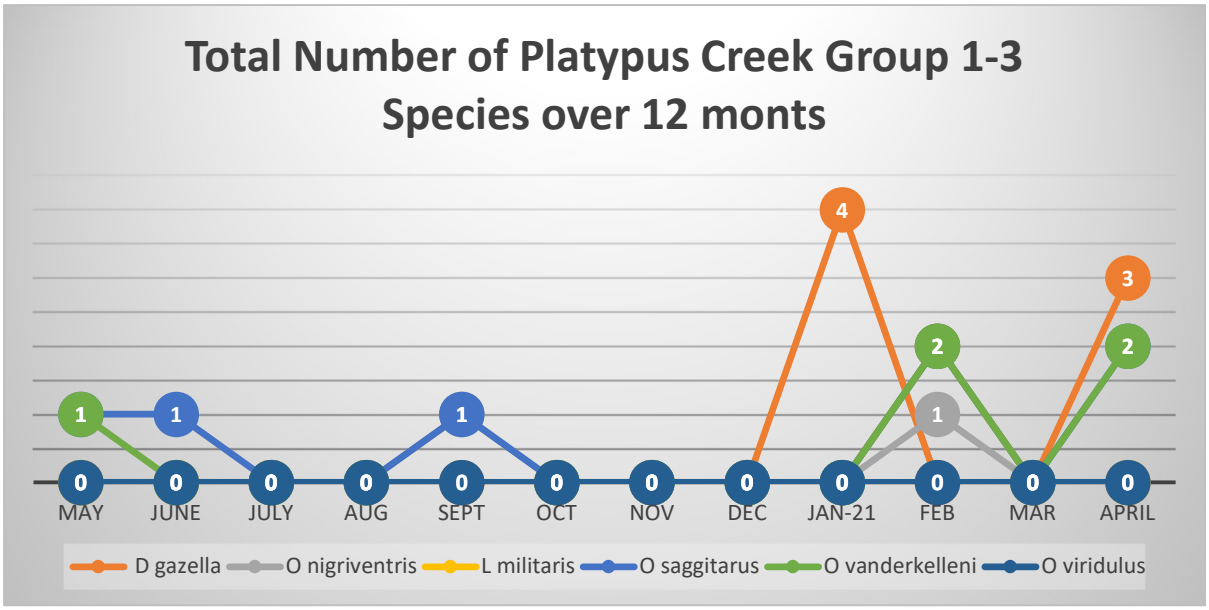


Figure 28: DBID total number of Group 1-3 dung beetle species collected from Platypus Creek May 2020 – April 2021

Figure 29 displays the peaks in abundance of Group Four and Five species of dung beetles across the 12 month collection period at Platypus Creek. The species most frequently collected throughout the year were the *H nomas* (with a peak of 11 individuals collected in September) and *S bicolour* (with a peak of 31 individuals collected in April).

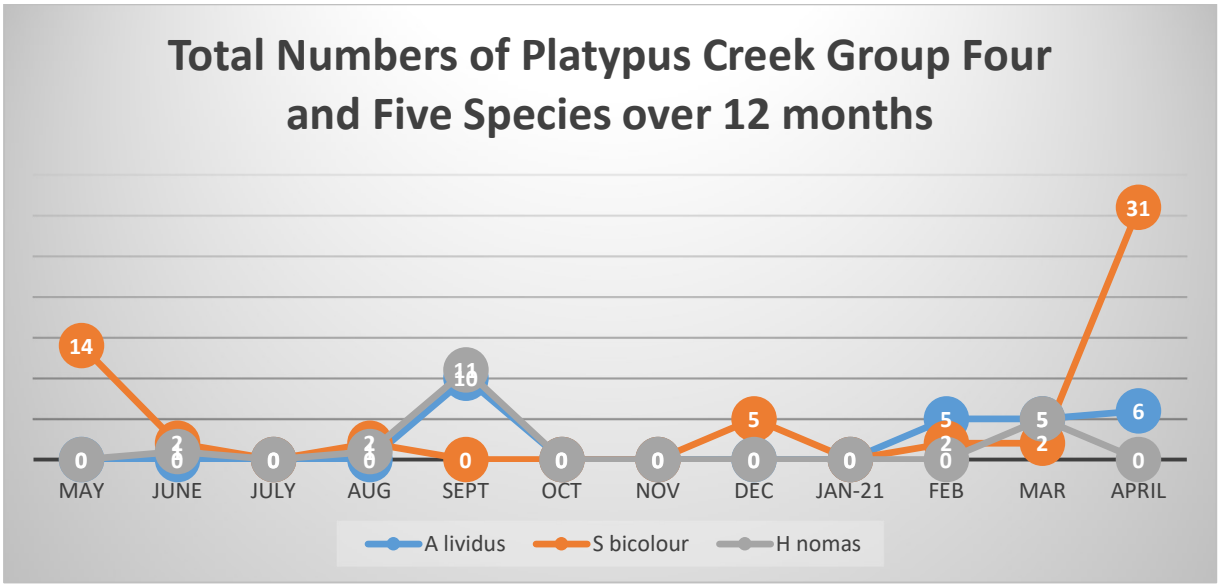


Figure 29: DBID total number of Group Two dung beetle species collected from Platypus Creek May 2020 – April 2021

Soil Microbiology

Soil samples were collected prior to the start of the DBID Project by Paul Edwards (PE) to evaluate the soil microbiological status of each farm. The paddock from which the soil sample was collected was selected by the farmer in consultation with Paul Edwards. PE collected and packaged the sample for delivery in accordance with his usual practice. Analysis (based upon the requirements of the Mikhail System) was undertaken by SWEP Analytical Laboratories (Victoria), and the results interpreted for the farmers by PE.

Overall, the soil balance results were similar across each of the farms, however there was a range of pH (5.0 – 7.9), and total organic carbon (3.73 – 6.65%) (Table 14). PE reported: "*Most of these soils are surviving on the high Carbon levels. In the biology section – they are fairly similar. Lactic acid is low which is good as elevated levels indicate soil health problems. Fungi dominate which is normal in low nutrient soils. Yeasts are elevated and working on the soil structure. Actinomycetes are working on breaking down the high Carbon levels.*"

Table 14: Summary of selected soil microbiology results of all farms

	Farm Wondecla	***Farm Platypus Creek***	***Farm Malanda***	***Farm FTW***	***Farm Biodynamic***	***Farm PCG***
Cation Balance %	28	24	21	38	41	45
Nutrient Balance %	40	33	40	40	48	49
Biology Balance %	49	49	49	31	34	34
Soil Balance %	39	35	37	36	41	43
pH (1:5 Water)	6.2	5.4	5	7.9	6.3	5.6
Total Organic Matter %	7.46	13	12.5	8.1	9.64	13.3
Total Organic Carbon %	3.73	6.5	6.25	4.05	4.82	6.65

Farm Management Practices including chemical usage

Usual stocking rates and farm practices were maintained by all the farmers throughout the DBID Project. At three time points during the year, farmers were asked to report any chemicals or biodynamic/organic treatments used on the cattle, or in the pastures, during the previous four months (Table 15). Among those farmers that used chemical parasiticides there was a reported preference for "beetle friendly" products and that the products were mostly used when there was an observed fly or tick infestation, and at weaning. Chlorfenvinphos was used by three farms on backrubs located in the paddocks.

There appeared to be little difference in diversity or abundance of dung beetles between the farms that used chemicals and those farms that did not. However, we did not specifically ask for the frequency or dosage rates of the products, so there could be differences in the frequency of application of these chemicals between farms. This may have an impact on dung beetle abundance and / or species variety at each farm. The two farms with the most diversity of species was Farm Biodynamic and Farm Wondecla: one a biodynamic dairy and the other a beef property using some chemicals (Table 15).

Table 15: Summary of Quarterly Survey Information: parasiticides used during DBID Project on each farm

	July 2020	***November 2020***	***May 2021***
Farm Wondecla	Moxidectin Permethrin	Moxidectin Fluazuron Chlorfenvinphos	Moxidectin
Farm Platypus Creek	nil	Chlorfenvinphos	nil
Farm Biodynamic	nil	nil	nil
Farm Malanda	nil	Moxidectin	nil
Farm FTW	nil	nil	nil
Farm PCG	Moxidectin Fluazuron Chlorfenvinphos	Moxidectin	Fly tags

The Weather

The DBID Project was conducted over a 12-month period (May 2020 – April 2021) thus including both wet and dry seasons. There were several days of frost in the region in July 2020 having a major negative effect on the pasture, especially for the Wondecla site. Other farms reported a light frost in some of the lower parts of their properties but without the damaging effects to pasture as seen by Farm Wondecla. Farmers reported that in general, temperatures at their farms were similar to previous annual averages. Unfortunately, the nearest BOM weather station with reliable temperature monitoring is at Mareeba Airport, some distance from any of the DBID Project farms.

Rainfall information during the DBID Project was assessed by the farmers during the quarterly surveys as less than usual, more than usual or about the same as usual (for that time of year) (Table 16). Self-assessment of the rainfall is subjective and determined by the individual farmer's record keeping – for example: Farm PCG and Farm Platypus Creek are on the same road, but each farmer assessed the rainfall differently. Generally speaking, the average rainfall for the region was slightly less than average, however, there was variation in rainfall totals between farms, and variation from the previous year within farms. Some of the farmers keep daily rainfall logs and provided supplemental information to the DBID Project. For example: Farm PCG received less rain for January – March 2021 than the same period in 2020. While there were some isolated storms in December 2020, the monsoonal rains arrived in January 2021 and provided a lot of rain in a relatively short time period at all farms. For example: Farm Wondecla received over half its average annual rainfall in just three weeks. For Farm PCG, the total rainfall for January 1-14, 2021 was the same amount for the entire month of January 2020[16]. In late April 2021, there was another significant rain event which provided the monthly average for most farms in a few days.

Table 16: Summary of Quarterly Survey Information: rainfall estimates at each farm

Survey (rainfall)	***May/July 2020***	***November 2020***	***May 2021***
Farm Wondecla	about the same	less than usual	more than usual
Farm Platypus Creek	about the same	more than usual	about the same
Farm Biodynamic	about the same	more than usual	about the same
Farm Malanda	less than usual	about the same	about the same
Farm FTW	about the same	less than usual	about the same
Farm PCG	about the same	less than usual	more than usual

[16] Personal correspondence Connie Petersen

Farmer Participation, Knowledge and Awareness

Six Atherton Tableland farmers (and, by default, their families) volunteered to participate in the project without any promise of tangible reward or compensation. Each farmer committed the time and effort to attend meetings, collect, kill, dry, package and post the dung beetles once a month for 12 months. Compliance with these tasks was high and nearly all farms collected and posted dung beetles every month. However, there were some missed collections and collections were lost by Australia Post in transit for identification.

Farmers were asked to complete a number of surveys throughout the course of the project and most farmers completed the surveys at the appointed times. Farmers were also asked to complete a pre and post DBID Project survey about their knowledge about dung beetles, what they hoped to gain from participating in the project and what they had learned during the project.

Prior to the start of the project, farmers reported a range of knowledge about dung beetles, from none, not much, a little to a lot of knowledge, about a range of subjects (Table 17). At the completion of the DBID Project, most of the farmers reported an increase in knowledge of most of the subjects (Table 17).

Table 17: Pre and Post knowledge survey by individual farm

What is your current level of knowledge about Dung Beetles?	**Farm Wondecla**	
	Pre	**Post**
on your property	A lot	A lot
and the different species	A lot	A lot
and their activity at certain times of the year on your property	A lot	A lot
and chemicals used on your property	A lot	A lot
and chemicals used generally in managing cattle	A little	A little
and their role in soil health	A lot	A lot
and their role in water health	A little	A lot
and their role in the ecosystem	A lot	A lot
What is your current level of knowledge about Dung Beetles?	**Farm Platypus Creek**	
	Pre	**Post**
on your property	A little	A lot
and the different species	None	A lot
and their activity at certain times of the year on your property	A little	A lot
and chemicals used on your property	A little	A lot
and chemicals used generally in managing cattle	A little	A lot
and their role in soil health	A little	A lot
and their role in water health	Not much	A lot
and their role in the ecosystem	Not much	A lot
What is your current level of knowledge about Dung Beetles?	**Farm Biodynamic**	
	Pre	**Post**
on your property	A lot	A lot
and the different species	A little	A lot

and their activity at certain times of the year on your property	A little	A lot
and chemicals used on your property	Don't use	Don't use
and chemicals used generally in managing cattle	Don't use	Don't use
and their role in soil health	A lot	A lot
and their role in water health	A little	A lot
and their role in the ecosystem	A lot	A lot
What is your current level of knowledge about Dung Beetles?	**Farm Malanda**	
	Pre	**Post**
on your property	None	Did not answer
and the different species	None	
and their activity at certain times of the year on your property	None	
and chemicals used on your property	A lot	
and chemicals used generally in managing cattle	A lot	
and their role in soil health	Not much	
and their role in water health	None	
and their role in the ecosystem	None	
What is your current level of knowledge about Dung Beetles?	**Farm FTW**	
	Pre	**Post**
on your property	A lot	A lot
and the different species	None	A lot
and their activity at certain times of the year on your property	A lot	A lot
and chemicals used on your property	A lot	A lot
and chemicals used generally in managing cattle	A lot	A lot
and their role in soil health	A lot	A lot
and their role in water health	A lot	A lot
and their role in the ecosystem	A lot	A lot
What is your current level of knowledge about Dung Beetles?	**Farm PCG**	
	Pre	**Post**
on your property	A little	A lot
and the different species	A little	A little
and their activity at certain times of the year on your property	A lot	Can always learn more
and chemicals used on your property	A little	A lot
and chemicals used generally in managing cattle	A little	A little
and their role in soil health	A little	A lot
and their role in water health	A little	A lot
and their role in the ecosystem	A little	A lot

Prior to the start of the dung beetle collection, farmers were asked why they had volunteered, and what they hoped to gain from taking part in the project. Obtaining knowledge about dung beetles was the most frequent response, as shown in these quotes from the farmers:

"To learn more about the range of species we have on the Tablelands",
"To improve my knowledge on dung beetles and to improve the collective knowledge of dung beetles on the Tablelands.",
"To have an understanding of the purpose and importance of dung beetles.",
"To learn different varieties of dung beetles to suit different soil types and rainfall.",
"Learn more" and
"To learn more on how dung beetles can improve our pastures and to be part of establishing more varieties of dung beetles on the Tablelands for the improvement of soil health in a natural/sustainable/biodynamic way."

Some farmers also wanted specific information about dung beetles on their own and in the area:

"To see how active dung beetles are on the property.",
"See what different varieties of DB are out there.",
"Species type. How active dung beetles are across the area. What species are active in the colder months. What beetle shortfall do we need to focus on.", and
"Why there isn't more dung beetles here?".

Farmers stated an interest in sharing ideas and increasing dung beetles: *"Good to see what others have got and share ideas with others. Has been my dream for last 20years to increase dung beetles.",* and *"To find out if there are there are beetle species on other properties in the Tablelands that we could perhaps introduce to our property."*

At completion of the DBID Project, farmers were asked if they had got what they wanted from being involved in the project, what was something they had learned, and what were they going to do about dung beetles in the future. One farmer involved her grandchildren in the collection of dung beetles and found the children were very enthusiastic helpers who became good at identifying dung beetle species: *"the kids would help collect them and pick them out of the bucket".*

Some farmers were disappointed with the lack of species diversity and abundance on their farms while others were surprised by the findings on their property. Farmers reported becoming beetle advocates to their peers, family and friends with one farmer stating *"I had colleagues at my office job bringing me beetles to identify and only one colleague actually has any cattle!"*

All the farmers reported that they had gained valuable knowledge about dung beetles during the course of the DBID Project: *"If I knew then what I know now… I wouldn't have purchased the species of beetles that I did– there are other species with more chance of survival up here."* One farmer was looking to continue researching and understanding dung beetles at the local level: *"now that we know the species that are here on the Tablelands, we should focus on the ones that we know work here, and understand why there are differences in the numbers of beetles at each farm."*

One farmer neatly summarised what all the farmers were reporting: *"What a marvellous job these little creatures do for our ecosystems. If we look after them the best we can, they will help us"*

Discussion

This is the first significant survey of the distribution and abundance of dung beetle species in Northern Queensland since 2002. The information obtained from the DBID Project builds on, and contributes to, the body of dung beetle species survey work nationally and within Queensland. The information obtained from this project can provide Atherton Tableland farmers locally appropriate recommendations as to which species of dung beetle might be best suited to their properties.

Dung Beetle Species Diversity and Abundance

We found 11 different introduced species of dung beetles at least once in the 12 months of collection and these species would appear to be the most logical selection for an Atherton Tableland farmer wishing to introduce dung beetles onto their property. However, we found relatively low numbers per dung pad of all species over the 12 months of collection across most farms. Dung beetle numbers are affected by multiple factors including but not limited to seasonal variability, quality of available dung, soil types and soil moisture and chemical usage. There is little research about how many dung beetles are to be expected or are optimal in one dung pad or the interactions and if competition, within one dung pad and among different species affects total numbers.

Five of the species found on all farms at least once in the collection time period, were released by the CSIRO to the region in the 1970s (*L militaris, D gazella, O vanderkelleni, H nomas, O sagittarius*) Interestingly, *O sagittarius* was released at Mareeba, at the northern end of the Tablelands some distance from the DBID Project sites, which may indicate that this species has good capacity for self-distribution. Two species found on all farms (*A lividus* and *S bicolour*) were not part of the original CSIRO releases.

We discuss each of the introduced dung beetle species found on all six farms in the DBID Project in detail below, and use data from the Qld Dung Beetle Project 2001-2002 and estimates from Doube[17] (2014) in this discussion of the DBID Project findings. Overall, the activity/seasonality of each species matched the trends found in the 2001-2002 Queensland Dung Beetle Project.

Photographs of the individual species are most clearly shown in dung beetle hard copy books and eBooks widely available to the public.

The **D gazella** was released by the CSIRO in 1968 and 1978 (including 12 colonies at multiple sites on the Atherton Tablelands) and is now established in all states except Victoria, South Australia and Tasmania. While this species is native to hot, arid, and semi-arid areas of sub-Saharan Africa, Africa, it is common in all high rainfall coastal regions of eastern southern Africa (and thus similar to the DBID farms with average rainfall between 1220mm – 1800mm). There is also now a view that *D. gazella* is a mix of about seven different species and this is currently being investigated in Canada[18]. One of these other D gazella species may be better suited to the Tableland.

Doube (2014) suggests a range of 1-50 D gazella beetles per pad could be reasonably expected in peak season under favourable conditions on the Atherton Tablelands. Despite three of the farms having received one colony each of this species during the MBPG Dung Beetle Project in 2016, the numbers of this species collected were low (less than 10 beetles per four dung pads) (Figure 30), and might be attributed to the volume of rain received in the region. Five of the six farms are on the "wet side" of the Tablelands, receiving on average up to 1800mm of rain annually. This species was found during the Qld Dung Beetle Project in 2001-2002 at the Malanda site in similar numbers to the DBID Project, but only found in one collection at the Ravenshoe site. The "dry side" farm (Farm Wondecla) had significantly more D gazella collections overall, with a peak in the rainy season of over 100 specimens from four dung pads. The results found from the Farm Wondecla site may suggest that properties with an average annual rainfall about or less than 1200mm might sustain this species more successfully than those with a higher rainfall (such as Malanda/Yungaburra).

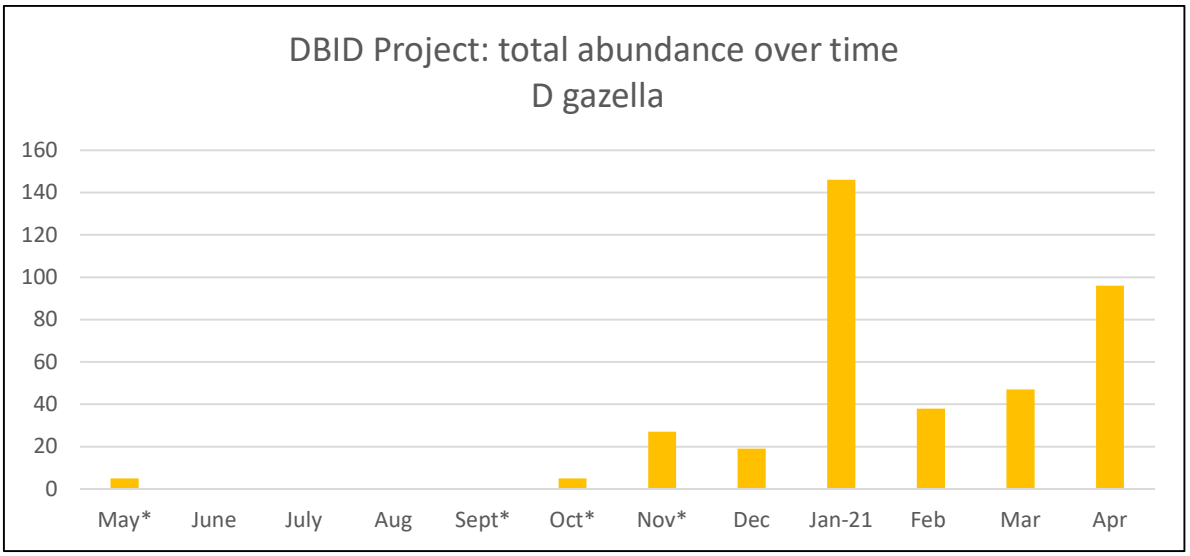


Figure 30: D gazella total abundance over the 12 months collection time period

[17] Doube & Marshall: Dung Down Under: dung beetles for Australia published 2014
[18] Personal correspondence Dr Bernard Doube

The **O sagittarius** is native to south-east Asia and now found along coastal regions of Qld, Northern Territory and the far north-eastern coastal NSW/QLD border. While we found this species at every farm, the numbers were low (generally less than 10 beetles per four dung pads), and occurrence was intermittent, peaking at the rainy season (Figure 31). Doube (2014) suggests a range of 1-10 O sagittarius beetles per pad could be reasonably expected in peak season under favourable conditions on the Atherton Tablelands. This species was not trapped at the Ravenshoe or Malanda site during the Qld Dung Beetle Project 2001-2002; however, samples were received after project training days from Tolga, Mt Molloy, Kairi and Yungaburra. These locations could geographically link the original CSIRO release sites with the DBID Project farms explaining the distribution across the Atherton Tablelands, and also suggest further distribution north (Mt Molloy) and east (Kairi).

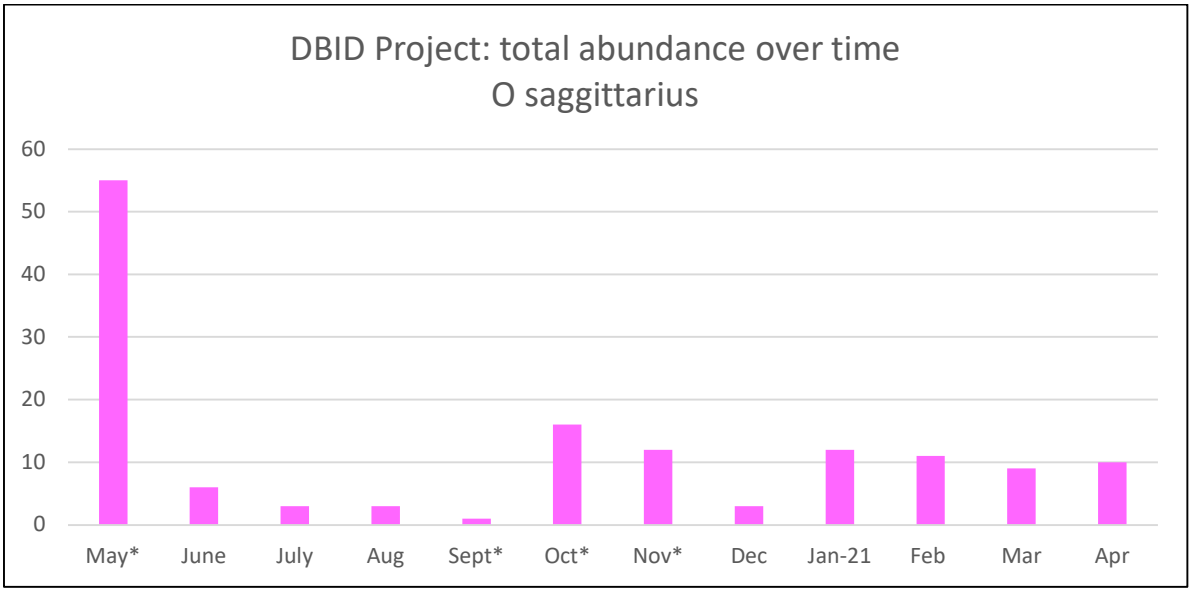


Figure 31: O sagittarius total abundance over the 12 months collection time period

The **O vanderkelleni** is native to the tropical highlands of sub-Saharan Africa, and lives at elevations above 1,800 meters with annual rainfall ranges from 800–2000 mm. The CSIRO released six colonies of this species on the Atherton Tablelands in the 1970s. During the Qld Dung Beetle Project 2001-2002, a small number of beetles of this species were found only at the Ravenshoe site, however specimens were received from two properties (not in the project) located in Beechmont, south-east Qld. Beechmont and Ravenshoe are both situated at high altitude and with relatively high average annual rainfall. Doube (2014) suggests a range of 1-10 this species of beetles per pad could be reasonably expected in peak season under favourable conditions on the Atherton Tablelands. We found this beetle species at every farm with a peak in numbers over November-December (Figure 32), the largest number (20 beetles from four dung pads) recorded at Farm PCG in November. Interestingly, this species was found in the "winter" or dry season at Farm Wondecla.

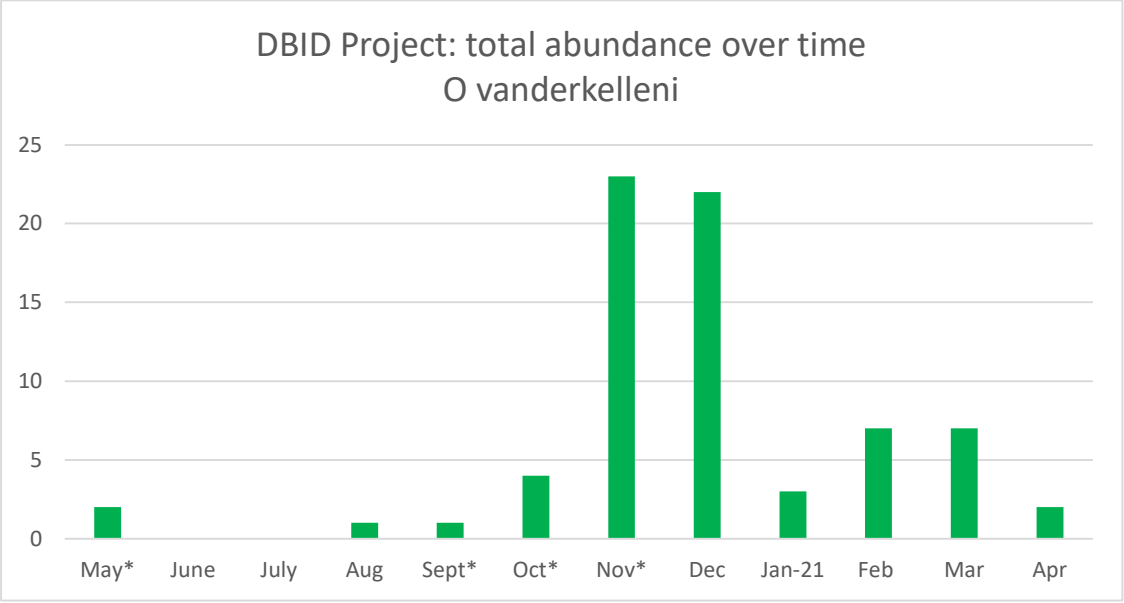


Figure 32: O vanderkelleni total abundance over the 12 months collection time period

L militaris is native to southern and eastern Africa and was released across eastern Qld (to the Cape) and northern Australia (to the Kimberley) by the CSIRO between 1968 and 1979 (and at one site on the Atherton Tablelands). This species is well established in the summer rainfall areas of Qld, northern NSW and the West Daly region of the NT. This beetle was found during the Qld Dung Beetle Project in 2001-2002 at only the Malanda site and in very low numbers. We found the L militaris in large numbers in January and April, and in low numbers in the dry season (Figure 33).

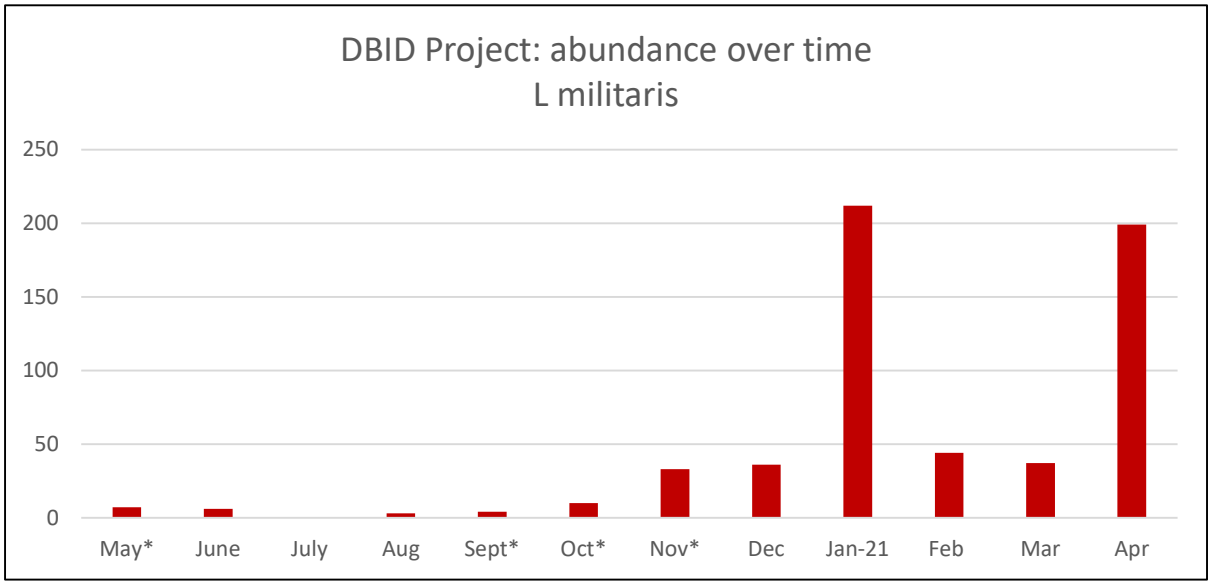


Figure 33: L militaris total abundance over the 12 months collection time period

Three species of beetles that are regarded as predatory dung beetles (*H nomas, A lividus, S bicolour*) were found on all farms and at most months of the year (Figure 4, 5). These beetles are smaller than the other introduced dung beetles and while not removing dung from the pasture, they provide valuable assistance to farmers in the reduction and control of fly[19].

Hister nomas is found in cattle dung and has significant benefits for farmers. Both the beetle adult and beetle larvae feed on fly larvae in the dung. Five species of the Hister genus were introduced to Australia by CSIRO with H nomas now found in NSW and Qld. This beetle was found at all DBID Project farms throughout the year but in small numbers therefore probably not impacting significantly on fly numbers. There was a slight increase in abundance with the onset of summer rains in December at some farms.

Sphaeridium bicolour is a small introduced beetle that lives in the cattle dung, and the distinctive white colouring at the end of its body makes it easy to identity. The adult beetle feeds on the dung and the larvae feeds on fly larvae. This beetle was found at all DBID Project farms throughout the year but in small numbers therefore probably not impacting significantly on fly numbers.

The Aphodius species including the **Aphodius lividus** were an accidental introduction to Australia and are small, long narrow beetles that feed and breed in the dung. These beetles are very small and challenging to collect, so numbers of this beetle in the DBID Project are underreported as some farmers did not collect every specimen for identification. Dr Doube suggests that *A. lividus* may be a dung breeding dung beetle, and as such, is a true dung beetle. Dr Doube also identified the ***Aphodius fimetarius*** and two Aphodius species yet to be conclusively confirmed during the 12-month collection period.

[19] Edwards Wilson Wright Introduced Dung Beetles in Australia a pocket field guide 3rd edition

What did we find that we didn't expect?

The DBID Project has uncovered some interesting and novel findings which have implications for future research.

Farmers need dung beetles to remove dung from the pasture all year round and the 'holy grail' of dung beetles in Australia is to have beetles that work in the winter. We found two beetles that were **active in the winter** (known as the dry season for Northern Australia) but in relatively low numbers. These species; *O nigriventris*, and *E intermedius*, thus have potential for further distribution to increase numbers on Atherton Tablelands properties to fill the winter gap.

The **E intermedius** is native to warm, moist parts of Africa, south of the Sahara so we would expect it to be suitable for conditions in FNQ. This dung beetle has established across most of the warmer parts of Australia and is absent in the drier central desert areas (central NT/WA, SA) and southern colder regions (Vic, southern NSW & WA, SA and Tas). The CSIRO introduced 10 colonies of this species into the Atherton Tablelands in the 1970s. This beetle was found during the Qld Dung Beetle Project in 2001-2002 at the two Tableland sites but in very low numbers (less than two per trap on average). Doube (2014) suggests a range of 10-50 E intermedius beetles per pad could be reasonably expected in peak season under favourable conditions on the Atherton Tablelands. We also found the beetle in low numbers (less than 10 per four pads) at most farms, and not at all on one farm (Figure 34).

Farm Wondecla was the exception, consistently having higher numbers of specimens than the other farms. This farm had identified this species on farm prior to the introduction of a colony in 2016 which may explain the greater abundance of this species at Farm Wondecla compared to other farms in the DBID Project. Farm Biodynamic also received this species in 2016 but had far fewer specimens compared to Farm Wondecla in the DBID Project, so may not have any of this species prior to the 2016 introduction. In contrast, Farm PCG did not receive any of this species in the MBPG Project yet had frequent collections over the year and relatively good numbers of this beetle in January. Despite being located near to this property, Farm Platypus Creek had no collection of E intermedius (except potentially in either of the two collections that went missing in the Post) during the project. However, this species was identified in June as part of another project.

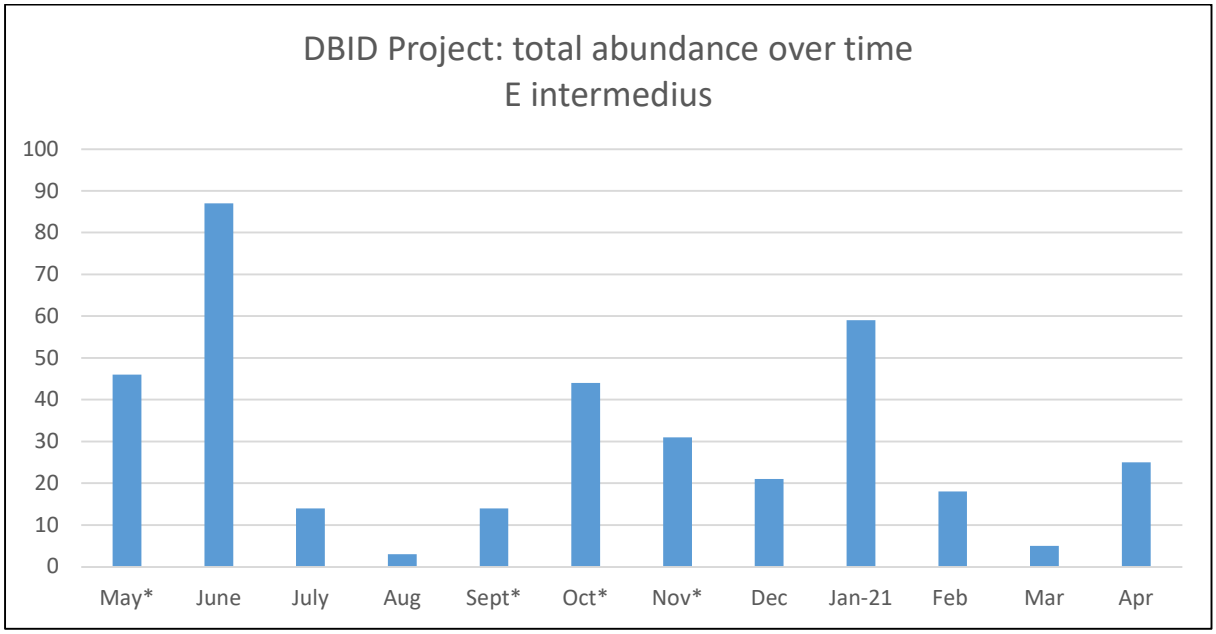


Figure 34: E intermedius total abundance over the 12 months collection time period

O nigriventris is native to the moist highlands in eastern Africa, and has established in the coastal NSW, southeast and highland tropical QLD regions of Australia. This species was trapped at sites with high altitude and high rainfall (seven sites in total including Ravenshoe and Malanda) in the Qld Dung Beetle Project in 2001-2002 with the largest collection at the Ravenshoe site. The majority of collections of this species in the DBID Project were made at Farm Wondecla, a property at higher altitude than the other farms. Peak catches were made in October (Figure 35) which is a little later that the August and February peaks found in the Qld Dung Beetle Project. Interestingly, a number of the major male specimens found at Farm Wondecla had downward pointing horns, rather than the upward pointing horn usually found[20]. There were no specimens of this species found at any time at Farm FTW.

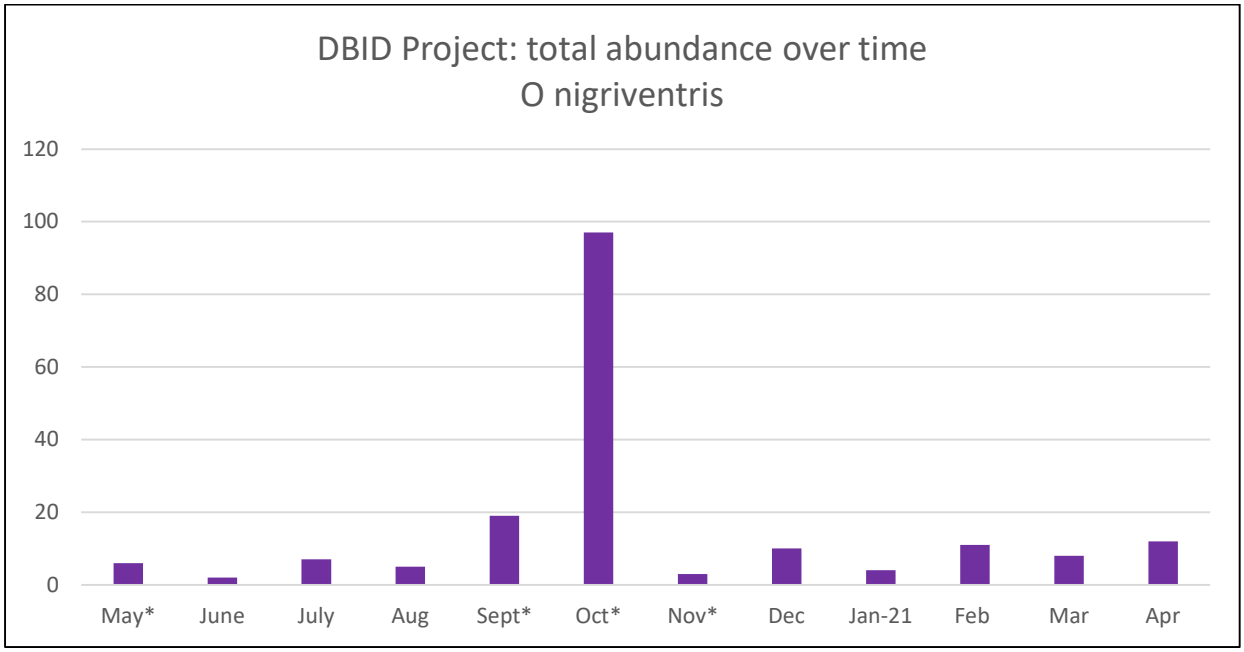


Figure 35: O nigriventris total abundance over the 12 months collection time period

Image: Atherton Tablelands. Photo Credit Tania Torrisi

[20] Personal correspondence Gail Abernethy

Only one species (*A lividus*) was found on all farms in the same month. During the 12-month time period of the DBID Project, we found some species were most abundant at different months of the year among the six farms. *L militaris* was at peak numbers in December for Farm FTW, in January for Farm Wondecla and in April for Farm PCG. Similarly, *D gazella* was most abundant in January for Farm Wondecla and in April for Farm FTW.

Farm Platypus Creek is separated by one property to Farm PCG, along the same road and on the same side of the road. They have similar farm management strategies (rotational grazing, beetle friendly chemicals), yet their dung beetle populations are very different. Farm Platypus Creek had very low numbers of any species of dung beetle and had one month when no beetles were found at all, whereas Farm PCG greater species diversity and abundance. Farm Platypus Creek was recently purchased by the owner (compared to 10-year ownership and management of Farm PCG) so the property could have been affected by any residual chemical usage or farm management practices unknown to the DBID Project.

Despite all farms trying to use dung beetle friendly chemicals and some farms having introduced dung beetle colonies onto their properties, **overall dung beetle numbers were low**. Some of the farms have been practicing dung beetle farm management strategies for over five years so we expected to find higher numbers. For all the species that Doube (2014) suggests would be present in the Cape York / Atherton region, expected numbers (abundance) of beetles per dung pad are small (1-10) except for *D gazella* (1-50) and *E intermedius* (10-50). We sampled four dung pads per collection, so, for some species, our numbers may in fact reflect Doube's (2014) estimates (if we divide by four, to compare one pad collection), and might be as abundant as we can expect.

There are a number of factors that may have influenced the numbers collected and these are detailed in the limitations section. It may be that the dung beetles require more time to establish significant populations in the region, or that population numbers have reached their maximum at the DBID Project farms. The effect of predation on the dung beetle population by birds such as ibis and cattle egret, and cane toads, is also unknown. All farmers in the DBID Project reported these animals on their farms.

Throughout this report, we have found similarities and differences in our findings compared with those of the Qld Dung Beetle Project 2001-2002. The activity of each species over time (average trap catch per month in the QLD state-wide 2001-2002 project) are similar to our Atherton Tablelands DBID Project findings. We have identified species on our farms in the DBID Project, not found in the Malanda site in the 2001-2002 survey, which may indicate the spread of the species across the region over time.

What did we expect to find, but did not?

There are species of introduced dung beetles which have been released, and identified, on the Atherton Tablelands which were not collected during the DBID Project.

O alexis is native to southern Europe and Africa, south of the Sahara and is established in most of Australia except Tasmania. While there were two colonies released on the Atherton Tablelands by the CSIRO in the 1970s and 11 colonies of this species released in the 2016 MBPG Dung Beetle Project there were no beetles of this species identified during the 12-month DBID Project. During the Qld Dung Beetle Project in 2001-2002, there were no collections of this species in the wettest sites across Qld, including Malanda and Ravenshoe. These findings suggest that this species may not be suited to the Atherton Tablelands.

O binodus, O taurus, O fulvus, O alexis, africanus species have all been introduced at some time and in small numbers to the Atherton Tablelands, yet we found no specimens during the 12month collection period. These are all southern species, and it would not be expected for them to survive in this environment and climate[21].

We found **no ball rolling dung beetles** in the DBID Project despite *S spinipes* being identified (in low numbers) in the region in previous historical surveys. The ball rolling dung beetles have quite different styles of using the dung compared to the other dung beetles. They fly during the day to fresh dung pads. *S.spinipes* makes a ball and rolls it away that day and so will not be caught, unless you are checking a very fresh day-time pad, whereas *S. rubrus* stays in the dung pad for a day then rolls a ball away. Both species attach the brood balls to vegetation (and not bury them underground) so our method of collection (collecting the dung pad and floating in water) may not have been appropriate to collect these species.

[21] Personal correspondence Dr Bernard Doube

Dung Beetle Diversity and Abundance and Climate, Soil Type, Soil Microbiology

The climate, soil type and soil moisture have important roles in how dung beetles can, or cannot, establish and thrive on farm and different species of dung beetle require different soil types. Farm Wondecla had a greater diversity of species (including native dung beetle species) and overall abundance compared to the other five farms in the DBID Project. Located on the western side of the Tablelands (climatic zone C5), Farm Wondecla has less rainfall and a different soil type (Kaban) compared to the five farms on the Malanda side of the Range (Pin Gin) (climatic zone C4)[22]. Despite these differences, there were a number of species identified on all six farms but collected at different time points across the year.

There was a definite change in beetle activity with the onset of the summer rains in December across all farms. All the farmers reported increased beetle activity at this time. For example: throughout the year, beetle specimens were collected by Farm Wondecla in the first week of each month and dung pad shredding was noticeably quicker in the second week of December compared to the first week. The owner stated *"I should have waited until the second week to collect the beetles. It was like a tap was turned on and all the beetles arrived".*

While there is little, if any, published literature about the effect of soil microbiology on the diversity and abundance of dung beetles, there appeared to be no significant differences between farms in soil microbiology.

Image: Atherton Tablelands. Photo Credit Tania Torrisi

Dung Beetle Diversity and Abundance and Farm Management Practices

Buffalo fly and other dung feeding flies need cattle dung to complete their lifecycle. Dung beetles can break the life cycle of the fly by removing the dung from the paddock and putting it into the ground. The farmers in the DBID Project who used chemical treatments on their cattle for fly and other parasites made a conscious effort to select "beetle friendly" products. We did not ask for detailed information about frequency or dose of the applications of chemicals so there may be differences between farms which may have an impact on dung beetle abundance and / or species variety (see limitations). However, there appeared to be no apparent difference between farms that did or did not use chemicals in dung beetle species diversity or abundance. For example, both Farm Biodynamic (who used no chemicals) and Farm Wondecla (who did use chemical products) both had greater

[22] Soils and agricultural land suitability of the Atherton Tablelands North Queensland 1999, Malcolm, Nagle et al

diversity of species compared to the other farms. There were chemicals commonly used across the farms to manage flies, ticks and worms and most of these were 'dung beetle friendly'.

Chlorfenvinphos (the active ingredient in both 'ExeyGuard' and 'Supona') is used as a spray on or in a backrub to control buffalo fly and is regarded as dung beetle friendly (Doube 2014) when used as per the label.

Permethrin is a synthetic pyrethroid commonly used as a fly and mite repellent which may have a negative effect on the dung beetle, therefore any use of this chemical must be re-examined by farmers wishing to maintain or increase their dung beetle population.

Fluazuron (brand name 'TixFix') is used to control the cattle tick by interrupting the tick life-cycle. Immature ticks die because they cannot moult to the following stage of development (i.e., larva to nymph or nymph to adult) and treated adult females cannot produce viable eggs. There is a 42day meat withholding period and ESI for this chemical and is not for use in cows which are producing or may in the future produce milk that may be used or processed for human consumption. Doube (2014) suggests that while this chemical has 'brief persistence', in either the animal's gut or dung, it is still likely to be toxic to the dung beetles. Therefore, any use of this product must be re-examined by farmers wishing to maintain or increase their dung beetle population.

Moxidectin (brand name 'Cydectin' or 'Maximus') is a used as a treatment and control of internal and external parasites of cattle. This chemical kills roundworms, and controls Ostertagia, lungworm and nodule worm, barber's pole worm and black scour worm. It is also used to control cattle tick for up to 21 days and does not have a meat and milk withholding period or export slaughter interval (ESI) for cattle. This product is regarded as dung beetle friendly (Doube 2014, and Virbac Product Information Sheet) when used as per the label. If farmers wish to rotate wormers, there are other options that are unlikely to be toxic to dung beetles, such some of the benzimidazoles (albendazole, fenbendazole) and Imidazothiazoles (levamisole) (Doube 2014) but research on the effect of these products on dung beetles is limited, if any at all.

The farmers in the DBID Project all volunteered to participate so are likely to have prior knowledge and awareness about the importance of chemical selection for the health of the dung beetle population. All the farmers reported at least 'a little' (with most reporting 'a lot') of knowledge about dung beetles and the use of chemicals, so this may explain the use of dung friendly product (or none at all) on the farms in the DBID Project. Farmer knowledge and awareness of chemical use on farm is vital to maintain or increase the resident dung beetle population.

Farmers Engagement with the DBID Project

The DBID Project was borne from discussions between farmers who came together in meetings supported by local NRM organisations. Remarkable NRM fleshed out the desire and issues needing to be resolved, shaped a project with the local farmers and approached Cape York NRM for funding support.

Beef and dairy producers come together in Yungaburra to set some priorities

Recognising the collective voice of the farmers, funding was granted in order to assist the local farmers to improve soil and water quality in the catchments flowing into the Great Barrier Reef. Dung beetles are a natural solution to decreasing nutrient runoff and improving soil health. The farmers' original goal was to increase the numbers of winter active dung beetles.

Initially, the farmers didn't know which species they had, in what numbers and when different species were most active or even present. Purchasing beetles to increase winter numbers without this information for the Atherton Tablelands would have been guess work.

Farmers talking to farmers is powerful engagement tool for innovative projects. The six farmers involved in the DBID Project have become advocates for the humble dung beetle. The farmers share their knowledge with their families, neighbours and peers. One of the farmers used posters created from this project to set up a booth at the local agricultural show to share the benefits of dung beetles and the knowledge gained in the project. "There was so much interest in the photos of the beetles" he reported. "People wanted to know what to look for in their own paddocks."

ON the LAND

Beetles may be silver bullet for Tableland soils

BY SALLY TURLEY

DISCOVERIES being made by local research group, "Dung Beetles on the Atherton Tablelands: Identification and Location" (DBID), could have huge benefits for the local beef and dairy industries.

Established by Gail Abernathy of Wondecla and Louise Gavin of Remarkable NRM, nine months ago, with funding support from Cape York and Terrain NRM, the project aimed to expand local knowledge about the presence and activities of Dung Beetles on the Tablelands and their benefits to the ecosystem and production.

But nine months in, the results being found by this dedicated group, which includes 6 dairy and beef operations from Wondecla, to Upper Barron, Malanda and Yungaburra, have moved way beyond those initial parameters.

"Our investigations have highlighted a gap in Dung Beetles activity during the winter months. Of the 17 native and 14 introduced species of beetle we have identified so far, none of them are actively removing enough dung in the winter months, which is something we want to change," Louise Gavin said.

"We have also discovered the presence of the introduced predatious species Hister nomas which feeds on fly larvea.

"The female lays her eggs under the cow pad and her larvae feed on fly larval in the pad, as well as finding and feeding on fly puparia in soil around the pad.

"Importantly, it was noted in the "Dung Beetle Survey of South East Queensland" which surveyed 18 properties throughout January 1999 that, when Dung Beetles are active enough, buffalo fly numbers reduced to levels where little or no chemical control was needed.

"A single cow pad can attract 2000 bush flies and CSIRO staff who had worked on the Dung Beetle buffalo fly program in Queensland, have stated that buffalo fly survival during experimental work had been reduced by 80% to 90% due to Dung Beetle activities."

Ms Abernathy believed the Dung Beetles could be a silver bullet for farmers.

"If they reduce flies we use less chemicals, which means less runoff to the reef. Australia's 250 native species evolved with our marsupials and are not adapted to clean up the larger, moister dung pads left by cattle," she said.

"Removing dung from pastures and shifting those nutrients underground, fertilises and aerates the soil, which improves pasture quality and reduces erosion, as well as breaking the parasite cycle. It is a win/win situation that is good for the farmers, the cattle, the environment and the reef."

Group members were required to collect four cow pad samples each month. The samples, must be at least 24 hours old, so it will have collected night and day flying species, and must include 3cm of the soil underneath, where eggs and larvae may be present.

Using the flotation technique, each pad is then tipped into 10 litres of water and agitated to remove the bugs. The collected bugs are then sent to leading Dung Beetle expert, Dr Bernard Doube in South Australia.

Ms Gavin said the project was hugely indebted to the Director of 'Dung Beetle Solutions International,' Dr Doube, for his subsidised rates, the generous sharing of his vast knowledge and his genuine desire for their project to succeed.

She said they hoped to continue building on the work done in former trials including the $23 million Dung Beetle Ecosystem Engineers (DBEE) 5 year project based in south west Queensland in 2019 and the Malanda Beef Plan Group Dung Beetle Project 2014-2016.

The DBEE project introduced new Dung Beetle species to southern Australia, created a beetle identification and location app, and aims to develop a Dung Beetle supply and distribution pipeline to producers.

In 2014 the Malanda group invited commercial Dung Beetle supplier, John Feehan (Soil Care Pty Ltd) to present at one of their farm field days and subsequently obtained a $65,000 grant through land care group, Terrain to purchase a number of dung beetle colonies. These were distributed across 18 Tableland properties from January to May 2016.

Unfortunately no baseline beetle species identification studies were carried out prior to their release making it impossible to know if the species had already existed on farms before hand.

Louise Gavin of Remarkable NRM demonstrates the flotation technique used to gather dung beetle specimens for their research program.

A lot of baseline data has been collected in the current project, including which species and in what numbers are already present on farms, their movements and activities throughout the year as well as a record of chemicals being used in each location.

Keen to continue this important work, Louise and Gail have applied for further funding and hope to both extend the trial out another 12 months and involve more properties, learn how far the beetles travel and introduce more beetles and different species to the area.

"We didn't know any of the species or when they were active when we started. We would like to test our knowledge further by looking at how the beetles are affected by our temperature range, chemical use, seasonal factors and predators such as birds and cane toads," Ms Gavin explained.

Ultimately the group hope to establish 'breeding trials locally to increase the numbers of species suited to the area. At over $1 head to buy, they would be a great resource to produce and with two thirds of the cattle herd in northern Australia, there would be a ready market for them. And quipped Ms Abernathy, they are quiet to have around, easy to muster and cheap to feed – the farmers' perfect accessory.

Limitations

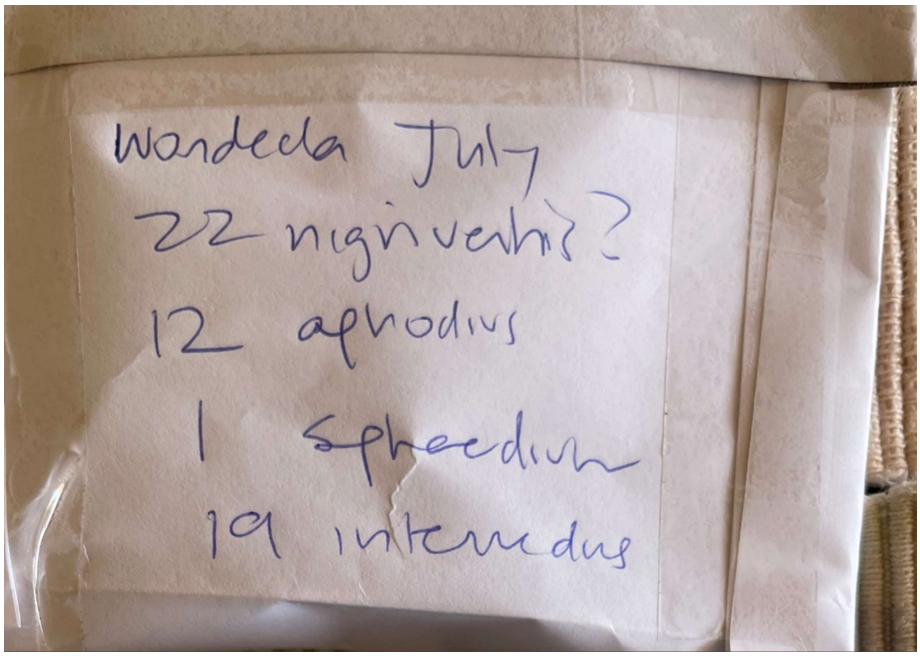
This project was driven and conducted by a group of six farmers and one Natural Resource Management representative. None of the group were entomologists or had any previous experience in scientific research about dung beetles. Prior to funding being obtained one of the participants undertook significant literature searching and reading to source similar projects on which to base this Atherton Tablelands project. Subsequently, the DBID Project has a very similar design to the Qld Dung Beetle Project 2001-2002. Throughout the data collection stage of the project, Dr Bernard Doube contributed expert advice and guidance to refine the details of beetle collection and preparation for transport.

The method of beetle collection is a potential limitation to project; not every beetle or every species may have been collected at each time point, and the collection may or may not be representative of the entire month. The floatation method of collecting beetles was selected as it requires minimal equipment, less expertise and less time to collect beetles, compared to pitfall traps, but is still successful at collecting large numbers of beetle specimens[23].

Participants were new to collecting dung beetles and despite one-on-one training, it took most participants at least two collections to become adept at the technique. However, once they had mastered the technique, they reported being very confident in identifying suitable cow pats to sample and mastered capturing floating beetles in the bucket. Identifying which of the insects in the collection were dung beetles was also reported as challenging for some participants at the start of the project, and they may have not collected all the dung beetles from their sample. This was especially relevant for the very small Aphodius species of dung beetle, where one participant had seen them in the bucket but had thought they were not dung beetles. This misunderstanding was clarified during the regular communications between LG and the participants, and subsequently all beetles collected were sent for identification.

[23] Fowler, F. How Dung Beetles affect Dung-Generated Greenhouse Gases in Cattle Pastures: Experimental Studies and Literature Review. (PhD Under the direction of Dr. David W. Watson).

Despite being asked to contribute considerable time and commitment to collect specimens monthly for one year, the farmers were diligent and committed to the project. There were incidences of missed collections within the first few months of the project. There were two instances of specimens being lost in delivery by Australia Post en route to Dr Doube for identification. Unfortunately, the specimens were from the same farm ("Farm Platypus Creek") and despite all efforts were unable to be located by Australia Post. There are limited options for researchers or members of the public to have dung beetles identified. Both of the commercial retail dung beetle business owners (Dr Doube, South Australia, and John Feehan, Canberra) will identify beetles for customers looking to purchase beetles, however, neither are located in Queensland. The DBEE group in Western Australia have produced an online dung beetle identification app, however, it requires a beetle specimen and/or a number of quality photographs to be uploaded to the app, which requires a good digital camera and is quite time consuming[24].



Beetle collection became challenging during the wet season for the participants. Grass in pastures flourished with the rain and also produced loose manure from the cattle. There was significant increase in dung beetle activity, and subsequent dung removal from the surface, with the onset of rain. The combination of these factors and regular rainfall washing the loose dung into the ground, made it challenging to find suitable dung pads to collect beetles from January to March.

In the quarterly surveys, farmers were not asked how frequently chemical products were used on the cattle, so our results only reflect the type of chemical used. There may be differences in application frequency between farms which may have an impact on dung beetle abundance and or species variety. This limitation will be addressed in any future identification projects.

We may not know all the introductions of dung beetle species to the Atherton Tablelands, as property owners in the region may have purchased dung beetle colonies for release on farm in the years since the original CSIRO releases. We found a number of native dung beetles throughout the year and while we had the expertise of a specialist dung beetle entomologist, identification of individual native species of dung beetle is challenging. Dr Doube will be collaborating with the Queensland Museum entomologist Dr Geoff Monteith to confirm the native dung beetle identifications.

[24] Personal correspondence Gail Abernethy

Conclusions

Dung beetles are vital to the removal of cattle dung from pastures to promote pasture growth, reduce chemical runoff, soil erosion and fly populations. The information obtained from the DBID Project can provide Atherton Tableland farmers locally relevant and appropriate recommendations as to which species of dung beetle would be best suited to this region. Based on our findings, we would suggest the E intermedius and the D gazella as the two preferred species for a farmer to purchase for the Tablelands if numbers of these species are low (less than 20 per pad). These dung beetles are established across most of Australia and likely to easily obtainable for purchase. Atherton Tableland farmers wishing to purchase dung beetles for release onto their properties would also be advised to first collect a sample of specimens from their property when the dung beetles are visibly active during the onset of summer storms or the rainy season and have them identified by an entomologist. This would provide the farmer with a baseline knowledge of the existent species on their farm for future monitoring of their dung beetle population.

The DBID Project has reinforced the need for more research into dung beetles in Northern Australia and showcased the enthusiasm and commitment of Atherton Tableland farmers to improving their pastures with dung beetles. The work initiated by the CSIRO in the 1970s to introduce dung beetles best suited for the Australian environment has progressed intermittently over time and mostly in southern Australia. Two thirds of the Australian beef cattle herd is located in Northern Australia, however, not all of the introduced species of dung beetle are able to live and thrive in the north, so it is vital that producers select the most appropriate species for their location when purchasing dung beetles for their properties. We have found a number of interesting and novel findings which will contribute to the knowledge base about the diversity and activity of dung beetle species on the Atherton Tablelands.

There appears to be a good variety of dung beetle species on the Atherton Tablelands, but the numbers per cattle pad are low. There are a number of factors which may influence the diversity and abundance of the dung beetle population on the Atherton Tablelands, and need further research and investigation, these include:

- The effect of the variability of soil type, rainfall and altitude on dung beetle populations within the region,
- The effect of predation by birds and cane toads on the dung beetle population,
- Assessment of the rate / efficiency of dung burial and on farm dung beetle abundance,
- The type and frequency of chemical usage on farm and the effect on dung beetle populations, and
- The effect of pasture management and stocking rate on dung quality and the dung beetle population.

Recommendations

That further work on identifying dung beetle species and their activity be undertaken across a number of diverse locations and cattle properties on the Atherton Tablelands and more broadly across Northern Australia, to identify region specific abundance and species diversity of dung beetles in cattle pasture.

That government and industry research and development funding be allocated to building dung beetle numbers in cattle pastures by the creation of dung beetle producer and public networks across Northern Australia with the aim of re-distributing dung beetles across properties.

That government and industry research and development funding be allocated to building dung beetle numbers in Northern Australian cattle pastures by the creation of one or more dung beetle nurseries in the north; with the aim of providing producers a commercial source of dung beetles appropriate for Northern Australia.

That industry funding be allocated to raising producer awareness and knowledge about the positive effects of dung beetle in dairy and beef operations, and best practice management strategies to maintain and build dung beetle numbers on farm.

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