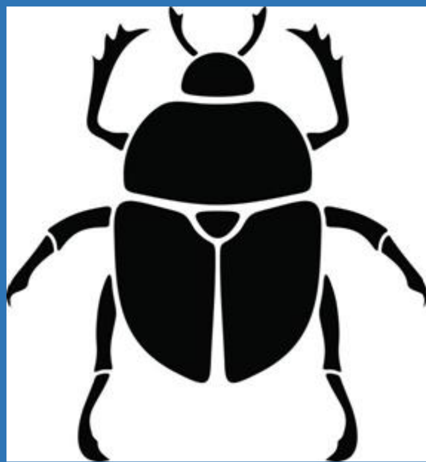
Dung Beetles on the Atherton Tablelands: Identification and Location Extension Project (DBID-E)

Final report October 2022



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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. The DBID Project was a first step to gather information about the regional distribution of the established species on the Tablelands and their precise seasonal activity. Helping to consolidate and build on this project is the aim of the DBID-E project.

With the help and support of Louise Gavin of Remarkable NRM and financial support from the Department of Agriculture, Water and the Environment, through funding from Australian Government's National Landcare Program a total of 15 beef and 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. Over 500 dung pads were examined and over 8500 beetles were collected and identified. Overall, there were eight species of introduced dung beetles, four predatory species and a nine species of native dung beetle. We found one specimen of an additional species (O alexis) not found in the previous DBID Project. 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 relatively easy to obtain 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 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. In short, 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 a multidisciplinary effort

including industry and university researchers, commercial dung beetle retailers, beef and dairy producers and Landcare networks across Northern Australia.

Foreword from Dr Bernard Doube

As indicated in the previous 'Dung beetles on the Atherton Tablelands' report, this study is an excellent example of citizen science in action, backed by scientific expertise. Special acknowledgement should go to Louise Gavin for securing funding to extend the original project, and for managing the project and ensuring that we all stayed on track, to Gail Abernethy for her outstanding technical skills, and to the collaborating volunteers who sampled and dispatched the beetles, without whom the project could not have succeeded. My partner, Loene, and I met with numbers of you in July 2022 and we learnt a lot about the Tableland beetles and their managers. The Tanya Murphy ABC interview with Gail (and me) went to local radio, then to national Country Breakfast, then to a national morning show, then to Robyn Williams' Science Show. Good PR for your project.

In an afterword at the end of the document, I have addressed the problem of how to define and delineate local dung beetle communities and I consider the Atherton Tableland surveys in relation to a 30-year data set (1972–2002) from Rockhampton Qld (900 km south). Seven of the nine true dung beetles (scarabs) found in the Atherton surveys occur in both locations, and the two that occur in the Atherton data but are missing from Rockhampton (*Onthophagus nigriventris*, *Onitis vanderkelleni)* are true high-rainfall species.

In the afterword I also consider the hypothesis of functional equivalence, in which species with similar ecological attributes (e.g. the three *Onitis* species) can be viewed as one functional group; for example, when attempting to assess the amount of dung buried by a community of dung beetles.

One of the common questions asked about regional dung beetle populations is 'which species are present and how abundant are they?' The two surveys go a long way towards an answer for the Atherton Tablelands but there remains a swag of unanswered new questions.

My conclusions are that among the true dung beetles:

- There were huge year-to-year variations in total numbers (up to 26-fold between years)
- Three groupings could be recognised in each location:
- dominant species
- subordinate species

- rare species.
- Some species, depending upon year, shifted between groupings.

Important differences between local regional communities on the Atherton Tableland were detected. The communities on Abernethy's and Holt's (on cleared eucalypt woodland, with moderate rainfall) were similar to those at Rockhampton, while the remainder (on cleared rainforest with high rainfall) were characterised by dominant species derived from high-rainfall regions overseas. This is not surprising, but reassuring to have it confirmed by good data.

The results of the two surveys have clearly identified autumn as a time when additional dung beetle activity is required. Fortunately, there is an introduced South African summer-rainfall strain of the autumn-active dung beetle *Onitis caffer* that is likely to be available next autumn. I strongly recommend that your group secure a supply of these beetles and:

- establish a series of test field cages to assess the suitability for *O. caffer* for a range of climatic conditions across the Atherton Tableland
- make a field release of one colony (1000 beetles) in the cleared eucalyptus region, where *O. caffer* is most likely to prosper

The next issues to be addressed are, of course, to evaluate how much dung *each community* buries and the benefits of such burial. But these are questions for the future.

In conclusion, I recommend this detailed report to you all and compliment the team, again, on a fine piece of work.

Bernard Doube OAM

Dr Bernard Doube, OAM
Dung Beetle Solutions International
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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

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[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

Council Catchment Groups, a commercial beetle supplier and two universities, the project has invested significant funding into dung beetle research in southern Australia[5].

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.

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5 DBEE website https://www.dungbeetles.com.au/

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

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

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

[8] Personal correspondence Bernie English DAF

[9] Australia's Introduced Dung Beetles: Original Releases and Redistributions, Tyndale-Biscoe, M. 1996

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 released	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

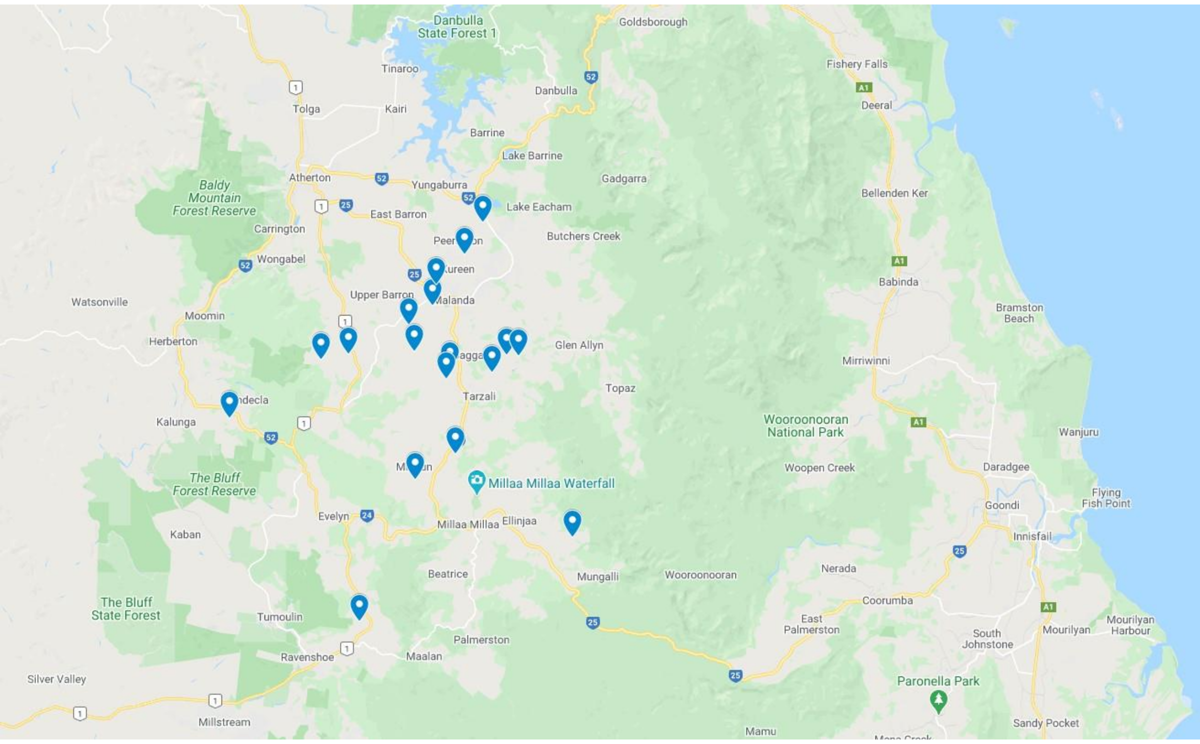
Today on the Atherton Tablelands, most of the intensive beef and dairy properties are situated around Malanda and to the south of Atherton with approximately 500 beef and dairy producers running 90,000 head of cattle[10]. The Malanda Beef Plan Group is a cattle producer network on the Atherton Tablelands.

[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

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

Remarkable NRM 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, and one of the key areas of producer interest was the need for work to be undertaken in the region about dung beetles. This producer led discussion prompted the project: *Dung Beetles on the Atherton Tablelands: Identification and Location*. Six Tableland producers (a mix of dairy, beef, biodynamic and conventional farming methods) volunteered to collect dung beetle specimens once a month for 12 months and to send the (deceased) specimens to Dr Bernard Doube (DungBeetle Solutions) for formal identification.

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 seven species of introduced dung beetles, three predatory species and an unspecified number native dung beetle species identified. 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. Beetle numbers across all farms increased with the onset of the summer (wet season) storms. The farmers reported that by participating in the DBID Project, they had learned more about the dung beetles and their importance to pasture and soil. The information obtained from the DBID Project provided Atherton Tableland farmers locally relevant and appropriate recommendations as to which species of dung beetle would be best suited to this region if the farmer wished to purchase beetles for their property: E intermedius and the D gazella.

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

Background

In 2020, on the back of the successful DBID Project, Louise Gavin (Remarkable NRM) was successful in obtaining another grant to extend and expand the DBID Project. Dung Beetles on the Atherton Tablelands: Identification and Location Extension Project (DBID-E) was a two year research and extension project which acknowledged and built on the work conducted previously. The DBID team continued to coordinate and manage the project, with Louise Gavin having financial oversight.

The project aimed to:

1) Conduct a second year of dung beetle identification on the DBID farms (six in total),
2) Identify dung beetle species for 12 months on an additional nine properties,
3) Determine the relative activity levels of the beetles over 12 (and 24) months (including all seasons),
4) Trial a biosecurity protocol for swapping dung beetles across properties,
5) Conduct an on-farm dung beetle raising trial,
6) Increase producer awareness of the ecosystem services dung beetles provide and their potential benefits to production,
7) Contribute to the Atlas of Living Australia database,
8) Purchase one colony of an appropriate dung beetle species for each of the 15 properties, and
9) Purchase a winter season species and monitor their activity and potential propagation into new areas over 2022.

Project Description

A project plan was 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 $90,468 was obtained from The Department of Agriculture, Water and the Environment 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). Gail Abernethy (threechookfarm) assisted with data entry and analysis for the final report. Five farmers from the DBID Project volunteered to participate in the DBID-E Project, and 10 new farmers volunteered. Specific details about each property are provided in the results section.

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. Gail Abernethy (GA) provided a practical, on-farm demonstration to nine of the new farmers to ensure consistency of specimen collection and packaging among the participants about how to collect and process the dung beetles for transport. Dung beetle specimens were collected from each property at approximately the same time of day and at the same time of month (eg the first Tuesday of each month at 10am) on a schedule convenient to the individual farmer. Based on the published literature, previous hands-on experience, and collection advice from John Feehan's website[12], the floatation method of collection specimens was used.

The floatation collection method is used in many scientific dung beetle 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. 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 were asked to report 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. Remarkable NRM facilitated a public forum workshop on February 12 2022 in Malanda, providing project information and summary results to that date to the group and members of the public. Dr Doube was in attendance via videoconference as due to COVID-19 restrictions, he could not attend in person. There were 28 persons in attendance and the event was well received.

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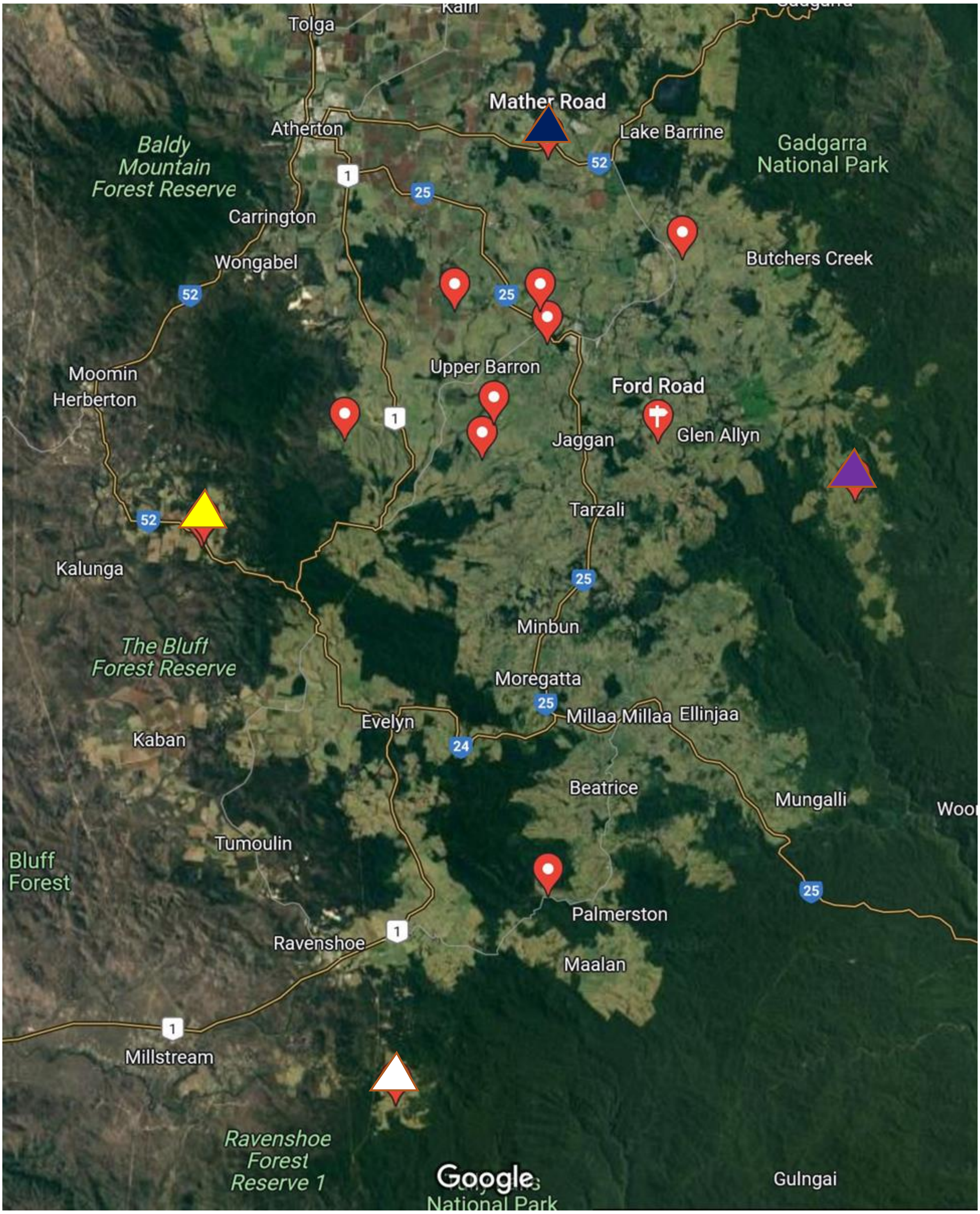
[12] https://dungbeetleexpert.com.au/dung-beetle-information/identifying-dung-beetles/

Participant Farm Information: the original DBID Farms

The information about each farm that is reported here has been provided by the owner. While the majority of farms ran beef cattle there were also two commercial dairy operations among the Project farms. Approximate location of each property are shown on Map 1 as red markers and coloured triangles. Maximum distance, as the crow flies, from blue triangle marker to white triangle marker is 47km and from purple triangle marker to yellow triangle marker is 31km.



Map 2: DBID Project farm site locations in relation to Cairns

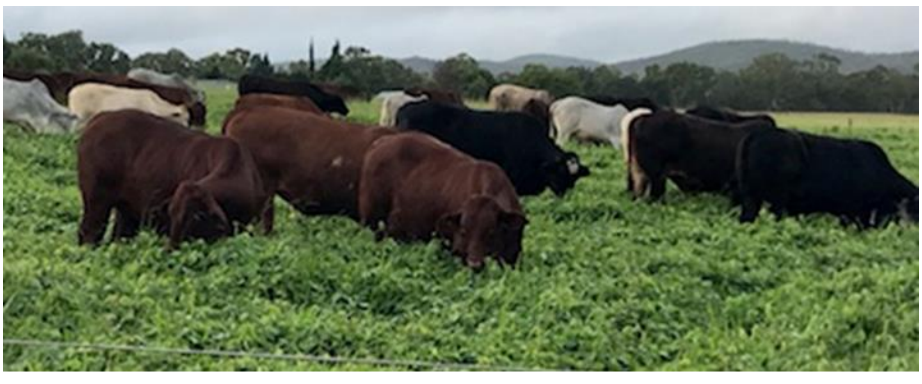
DBID Farm Wondecla: 'threechookfarm'

'threechookfarm' is located in Wondecla approximately 10km south of Herberton. The 90-acre property was purchased by the current owners in 2012 to fatten store steers for the local butcher market. 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 (2013-2021) 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]. 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. Kangaroo, wallaby, cane toads, ibis and cattle egrets are also regularly seen in the paddocks. The neighbouring properties also run beef cattle. This property is located at the yellow triangle marker on Map 1.

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. 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. The owners have introduced dung beetles onto the property (Table 2).

Table 2: beetles identified and released on Farm Wondecla 2014-2021

identified 2014	released 2014	identified 2016	released 2016	identified 2021
O viridulus	O binodus (500)	O vanderkelleni	O alexis (1000)	D gazella
O nigriventris	O taurus (500)	O sagittarius	E intermedius (1000)	L militaris
E intermedius	O fulvus (500)	L militaris	D gazella (1000)	E intermedius
H nomas		unspecified natives	3 species mixture (500)	O nigriventris
				O sagittarius
				O vanderkelleni
				O viridulus
				H nomas
				S bicolour
				A lividus
				A fimetarius



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

DBID 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 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. Stock numbers and grazing rotation through the paddocks is determined by the condition and growth cycle of the grasses. 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. 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. 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 owners introduced dung beetles onto the property (Table 3).

Table 3: beetles identified and released on Farm PCG 2016-2021

released	**identified**
2016	**2021**
O alexis (1000)	D gazella
D gazella (1000)	L militaris
	E intermedius
	O nigriventris
	O sagittarius
	O vanderkelleni
	H nomas
	S bicolour
	A lividus
	A fimetarius

DBID 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 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 climate is semi-temperate with a wet and dry season, however at around 708m above sea level, the winters are cool with heavy and the occasional light frost. Rainfall per year ranges between 660-1200mm depending on the season. This property is located at the blue triangle in Map 1. In 2021, the farmer destocked his cattle and then ran agistee stock on the property. Beetle collection was undertaken by LG during the DBID Project and by the farm owner for the DBID-E Project.

Table 4: beetles identified and released on Farm FTW 2020-2021

identified
2021
D gazella
L militaris
E intermedius
O sagittarius
O vanderkelleni
H nomas
S bicolour
A lividus
A fimetarius

DBID Farm "Biodynamic"

'Farm Biodynamic" is a 200 head biodynamic dairy farm located near Malanda, elevation approximately 744m, on a sloping block, 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 300 acre property is red basalt soil with 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. The owners introduced dung beetles onto the property during the MBPG Dung Beetle Project (Table 5).

Table 5: beetles identified and released on Farm Biodynamic 2016-2021

released	identified
2016	**2021**
E intermedius (1000)	D gazella
D gazella (1000)	L militaris
	E intermedius
	O nigriventris
	O sagittarius
	O vanderkelleni
	O viridulus
	H nomas
	S bicolour
	A lividus

DBID 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. The soil type is Pin Gin and this property is situated on the same road, and same side of the road, as Farm PCG. The neighbouring properties also run beef cattle or dairy herds. The climate is semi-temperate with a wet and dry season, however at around 832m above sea level, the winters are cool, but the property does not get frost. The average rainfall is 1800mm with the majority of the rainfall occurring during January to March.

The property runs 110 head of Brangus breeding cows on pastures consisting of Seteria, Brachiaria and legumes. The cattle rotationally graze the paddocks, the speed of which 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 owners have introduced dung beetles colonies to the property since 2016 (Table 6).

Table 6: beetles identified and released on Farm Platypus Creek 2016-2021

Identified 2021	Released 2021
D gazella	D gazella O nigriventris O vanderkelleni (mixture of total 250 individuals)
L militaris	
O nigriventris	
O sagittarius	
O vanderkelleni	
H nomas	
S bicolour	
A lividus	

Participant Farm Information: the DBID-E new project farms

Farm “CedarValley”

This 800 acre property is located in Upper Barron and runs a beef breeding operation of 400head. The soil is red basalt and the pasture is a mixture of brachiaria, Seteria, guinea grass and legumes. Annual rainfall ranges from 1200mm to 1600mm and frost can affect some parts of the property. Cydectin pour on is applied to the weaner cattle when required and these cattle are restricted to one area of the property. The owner frequently sees wallabies, cane toads and many egrets in the paddocks. The owners introduced dung beetles colonies to the property during the 2016 MBPG Dung Beetle Project.

Farm “Cadaghi”

This property is a neighbour of Farm Wondecla. The property size is 50 acres on which the owners run 12 cows and a bull and sell off the weaned calves. The pasture is a mixture of brachiari, wyn cassia, stylo spp and Tinaroo glycine. Prior to purchase by the current owners, the property also ran a similar breeding operation and market garden. The owners do not use any chemicals on the cattle except for an organic fly spray (applied by hand spray to each animal) when flies are noticeably bad on the cattle. Worming of the two horses on the property is determined by faecal egg counts. The owners have observed dung beetle activity in the dung prior to the DBID-E Project. This property is located at the yellow triangle marker on Map 1.

Farm “Barefoot”

This property is located in the Ravenshoe area (920m altitude) and borders the rainforest. The owners utilise regenerative, biodynamic and biological farming management practices. They run 45-60 beef cattle breeders and a market garden on 200 acres. Based on the number of flies on the cattle, the owners may apply a fly repellent on 2-3 cattle (not all the cattle) in the herd to reduce the effect of fly. The soil is red clay and the pastures contain Bracchiaria, Seteria and legumes, with an average rainfall of 1.5m to 2.0m annually. The owners regularly see wallabies, bandicoots, egrets, wild pigs and cane toads in the paddocks. This property is located at the white triangle marker on Map 1.

Farm “Bundarra”

This property is located on the edge of the Malanda township. The owners introduced dung beetle colonies to the property during the 2016 MBPG Dung Beetle Project. Farm Bundarra is a beef property running 120 breeders on 240 acres. The soil type is predominantly pingin and the grasses a mixture of Brachiari, Seteria and legumes. The owner reports an average rainfall of 1500mm. Ticks are treated with cydectin when visible on the animals and supona spray is used occasionally as a fly repellent. Cane toads, egrets and ibis are regular visitors to the paddocks, but the owner rarely sees marsupials on the property.

Farm

“Topaz”

This 100 acre property is located in Glen Allyn (altitude 692m) and runs up to 45 head of beef cattle. The pastures consist of Seteria, Bracchiaria, and legumes and the soil is red dirt, volcanic. The neighbouring properties also run beef cattle. Cattle egrets and cassowary have been seen on the property but no marsupials, or cane toads. The owner purchased this property as a vacant block (ie no cattle) within the previous 3 years. There has been a program of spot spraying woody weeds and Navua sedge since the purchase of the property. Chemicals are used sparingly: weaner cattle are wormed with a beetle friendly chemical (Genesis) if ticks are observed and fly tags applied if flies are noticeably bad on the cattle. This property is located at the purple triangle marker on Map 1.

Farm “Quinola”

The owners took over this 450acre dairy property, located in Upper Barron, in 2020 and run 150 milking cows. The pasture is a mixture of Rhodes, Bracchiaria, Seteria, rye grass, chicory and clover on a clay loam soil. The neighbouring properties are a cropping cane farm and a flower farm. The calves have a Genesis pour on or Nilverm drench and a tick plunge dip is used as required 2-3 times per year. The owners see wallabies, bandicoots, egrets, and cane toads in the paddocks.

Farm "BeatriceHills"

This property is located in the Ravenshoe area (altitude 943m). The red soil supports Seteria, Bracchiaria and kikuyu grasses on 120 acres (20 acres forest), with a 40 head breeding Brangus herd. Average annual rainfall is estimated to be around 2.5meters. The owners have seen cattle egrets, cane toads, tree kangaroo and cassowary on the property. There has been a program of spot spraying woody weeds and Navua sedge since the purchase of the property. Parasites including ticks and flies are treated when required with dectamax, nucidol and barricade. Dung beetle activity has been observed by the owners on the property but not formally identified.

Farm "Jaggan"

Farm Jaggan is a 180acre property located approximately 10km south of Malanda, around 780 m above sea level with a semi-temperate climate, occasional light frost and an average annual rainfall around 2200 mm. The property was originally cleared in 1912 and used as a milk producing dairy until transitioning to beef cattle in the 1970s. For five years during the 1990s, half the property was planted with potatoes alongside the beef operation. The property runs 50 Brangus breeders, with weaners sold on to finishing properties at 12 months of age. Stock are rotated through each paddock at a rate determined by the condition and growth of the grasses. Supona backrub and cydectin pour on are applied to the cattle when required. The owner frequently sees wallabies, bandicoots, cane toads and the occasional egret in the paddock. Dung beetle colonies were released onto the property in 2016 and 2022 during the MBPG Dung Beetle Project.

There was a change of owner in January when the property was destocked from January to April and collections of beetles did not occur.

Farm WinWe and Farm Bro-ton

Farms WinWe located in the Lake Eacham area and runs a beef fattening operation on 300acres (only collected two months of specimens). Cydectin pour on is applied to the cattle twice per year and the cattle have fly tags to repel flies. The owner rarely sees native animals, egrets or cane toads n the paddocks. The owner states that he purchased and released two colonies of dung beetles approximately 5-8 years prior to the DBID-E Project but could not recall which species. Farm Bro-Ton (joined in July and collected four months of specimens)

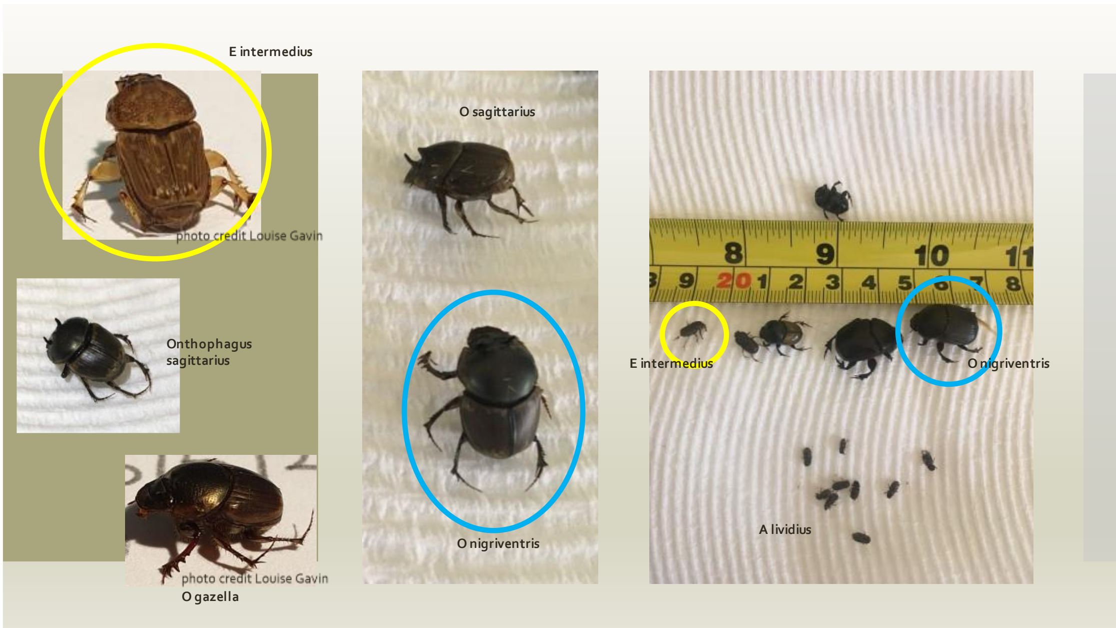
Results

The dataset (monthly identification of dung beetles from 15 farms) is incomplete. For various reasons outside the control of the project, there were a number of farms that did not provide specimens for identification every month, and some collected specimens were lost in transit to South Australia. We present detailed data from the farms with the most complete data sets and summarise briefly the remainder farms.

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, O alexis.*
- 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.



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

Beetle Identification, Seasonality and Abundance: Overall Trends and Findings

As reported above, the dung beetle identification dataset is incomplete as not all farms collected specimens every month and some specimens were lost in transit. We report the findings of the farms with the most complete datasets and the DBID Project farms in more detail with summary tables provided of the other farms. In general for the DBID Project farms, there was overall a small increase in the total number of specimens collected compared to the previous year. Three DBID Project farms identified dung beetle species not found in the previous year on their farm including one single individual of a new species for either Project – the O alexis found at Farm Wondecla. Comparative tables for the two years of data for the DBID Project farms are attached in the appendix.

Over the 12 months of the study a total of 504 dung pads were examined and over 8600 beetles were collected and identified. The peak beetle activity occurred with the onset of the summer storms in December (Figure 1). Figure 1 shows the number of farms which contributed to the total number of beetles collected for that month.

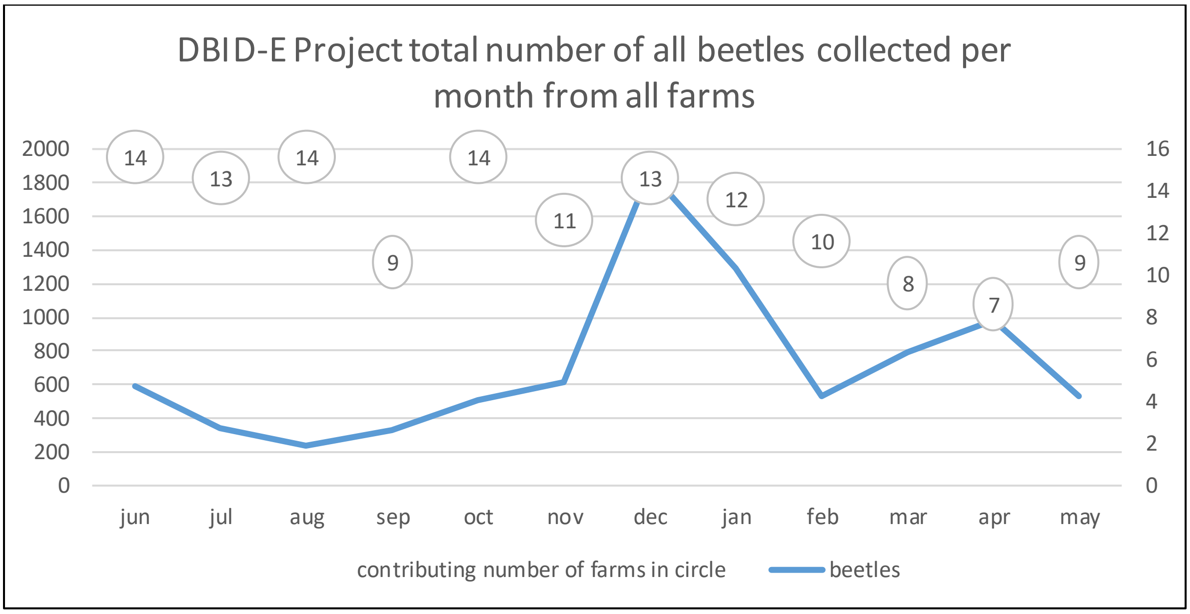


Figure 1: DBID-E Project total number of all beetles collected per month from all farms June 2020 – May 2022

Overall, there were eight species of introduced dung beetles, four predatory species and nine species of native dung beetles (none of which were abundant) (Tables 7, 8).

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 farms were found. Despite missing some months of collection over the year, every farm collected *O vanderkelleni* at least once and most farms collected specimens of *D gazella, L militaris, O sagittarius, O nigriventris, A lividus, H nomas, S bicolour*) (Tables 7, 8).

Table 7: DBID-E Identification (Groups 1-3) by Site: June 2021 to May 2022 (for *DBID farms* * indicates species found in DBID-E timeframe only)

E intermedius	**L militaris**	**D gazella**	**O nigriventris**	**O sagittarius**	**O vanderkelleni**	**O viridulus**	**O alexis**
Platypus Creek *	Platypus Creek	Platypus Creek	Platypus Creek	Platypus Creek	Platypus Creek	*Platypus Creek**	
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	*Wondecla**
CedarValley	CedarValley	CedarValley	CedarValley	CedarValley	CedarValley		
Cadaghi	Cadaghi	Cadaghi	Cadaghi	Cadaghi	Cadaghi	Cadaghi	
BeatriceHills		BeatriceHills	BeatriceHills		BeatriceHills		
Barefoot	Barefoot	Barefoot	Barefoot	Barefoot	Barefoot		
Bundarra	Bundarra	Bundarra	Bundarra	Bundarra	Bundarra		
	Quinola	Quinola	Quinola	Quinola	Quinola		
		Topaz	Topaz	Topaz	Topaz		
	Jaggan	Jaggan	Jaggan	Jaggan	Jaggan		
Bro-Ton		Bro-Ton		Bro-Ton	Bro-Ton		
	WinWe		WinWe	WinWe	WinWe		

Table 8: DBID-E Identification (Group 4 and 5) by Site: June 2021 to May 2022 (for *DBID farms* * indicates species found in DBID-E timeframe only)

A lividus	**A fimetarius**	**H nomas**	**S bicolour**
Platypus Creek	*Platypus Creek**	Platypus Creek	Platypus Creek
Farm FTW	Farm FTW	Farm FTW	Farm FTW
Biodynamic	*Biodynamic**	Biodynamic	Biodynamic
Farm PCG	Farm PCG	Farm PCG	Farm PCG
Wondecla	Wondecla	Wondecla	Wondecla
CedarValley		CedarValley	CedarValley
Cadaghi	Cadaghi	Cadaghi	Cadaghi
BeatriceHills	BeatriceHills	BeatriceHills	BeatriceHills
Barefoot		Barefoot	Barefoot
Bundarra		Bundarra	Bundarra
Quinola	Quinola	Quinola	Quinola
		Topaz	Topaz
		Jaggan	Jaggan
		Bro-Ton	
WinWe			WinWe

It was rare for every farm to collect the same species of introduced dung beetle in the same month but more likely to occur during the onset of the summer storms (November – January) (Table 9). O vanderkelleni was active on a number of farms in June and October (Table 9).

Table 9: DBID-E: June 2021 to May 2022 Number of farms that collected at least one specimen per species by month (caveat – not all farms collected for all 12 months)

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
E intermedius	5	2	3	2	5	5	6	6	3	3	4	2
L militaris	9	5	5	2	2	6	2	6	5	3	5	3
D gazella	4	3	2	1	8	11	10	12	8	6	7	8
O alexis	-	-	-	-	-	-	-	-	-	-	-	1
O nigriventris	8	8	6	6	9	8	8	11	7	3	5	3
O sagittarius	6	4	5	7	4	7	4	11	6	5	6	6
O vanderkelleni	10	6	9	7	11	9	7	8	6	5	6	4
O viridulus	-	-	-	-	1	3	-	-	-	1	-	1
A lividus	9	1	5	4	4	5	9	5	6	7	6	4
A fimetarius	-	5	-	-	-	2	-	2	3	3	2	2
H nomas	11	11	8	9	12	9	6	10	9	4	7	5
S bicolour	10	9	8	7	6	6	4	8	7	5	6	7

Farm Specific Dung Beetle Identification: the original farms

Farm Wondecla Peak activity occurred from December to June at this farm and overall numbers were greater than most other farms. Dung beetles had been previously identified on this farm (Table 2) prior to the introduction of additional dung beetle colonies. However, there were six species introduced in either 2014 or 2016 (Table 2), that were not identified at any time during the DBID or the DBID-E Projects*: O binodus, O taurus, O fulvus, 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. Interestingly, there was a single beetle specimen of the O alexis species found in May 2022 on this farm – the only *O alexis* found in either the DBID or DBID-E Projects in any of the farms despite this species also being introduced on a number of farms in the MBPG Dung Beetle Project.

O nigriventris was collected in most months in small numbers (Table 10), at Farm Wondecla, but was abundant and active in July and September. These were different months to the DBID Project when this species was most active in October-November. As seen in the DBID Project, 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 2). 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. However, there were fewer of these beetles collected on this farm compared to the numbers collected during the DBID Project.

Farm Wondecla has found more native dung beetles than the other Project farms. This may be due to the number of regular kangaroo visitors to the paddocks and the neighbouring eucalyptus forest.

Unfortunately, the identification of the February sample was not recorded. However, the owner maintained a record of the number of beetles sent and an approximation of the species. Based on the photos we can assume the same species as January were present (and as for Farm Cadaghi).

Table 10: DBID-E Project: Farm Wondecla monthly identification and abundance June 2021 – May 2022

WONDECLA	June	July	August	September	October	November	December	January	February	March	April	May
E intermedius	24	16	8	47	43	25	17	77	yes	4	12	21
L militaris	56	17	4		1	1	48	14	yes	35	1	10
D gazella	11	1	1			4	115	164	yes	152	46	66
O alexis												1
O nigriventris	8	23	8	44	4	5	6	2	yes	1	13	
O saggitarus	12	15	1	11	12	1	3	8	yes	70	114	147
O vanderkelleni	5		1	10	6	6	2	6	yes	1	2	5
O viridulus						1				1		
A lividus	3	12	2	9	2	2	15	9	2	10	2	3
A fimetarius						1				19		
S bicolour	21	1	28	5	3	1			3	8	24	10
H nomas	6			2	5	1	2	1		1	1	3
GRAND TOTAL	**146**	**85**	**53**	**130**	**76**	**48**	**208**	**281**	**167**	**302**	**215**	**266**

Figure 2 displays the peaks in abundance of Group One dung beetles across the 12 month collection period at Farm Wondecla. E intermedius peaked in September (compared to June in the DBID Project). The same pattern of increased activity with the onset of the summer storms seen in the DBID Project is seen in the DBID-E Project.

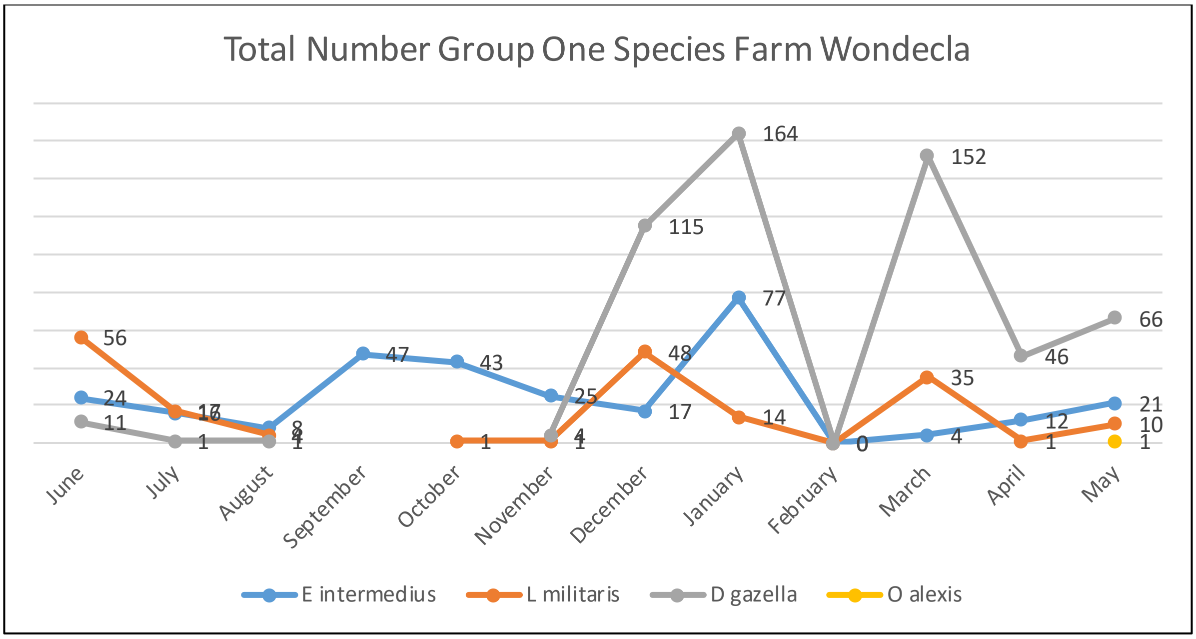


Figure 2: DBID-E total number of Group One dung beetle species collected from Wondecla June 2021 – May 2022

Figure 3 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Farm Wondecla. *O saggitarus* numbers increased over March to April and numbers were considerably higher than that found in the peak of the May DBID Project collection. *O nigriventris* peaked in September – a month earlier than the October peak recorded in the DBID Project.

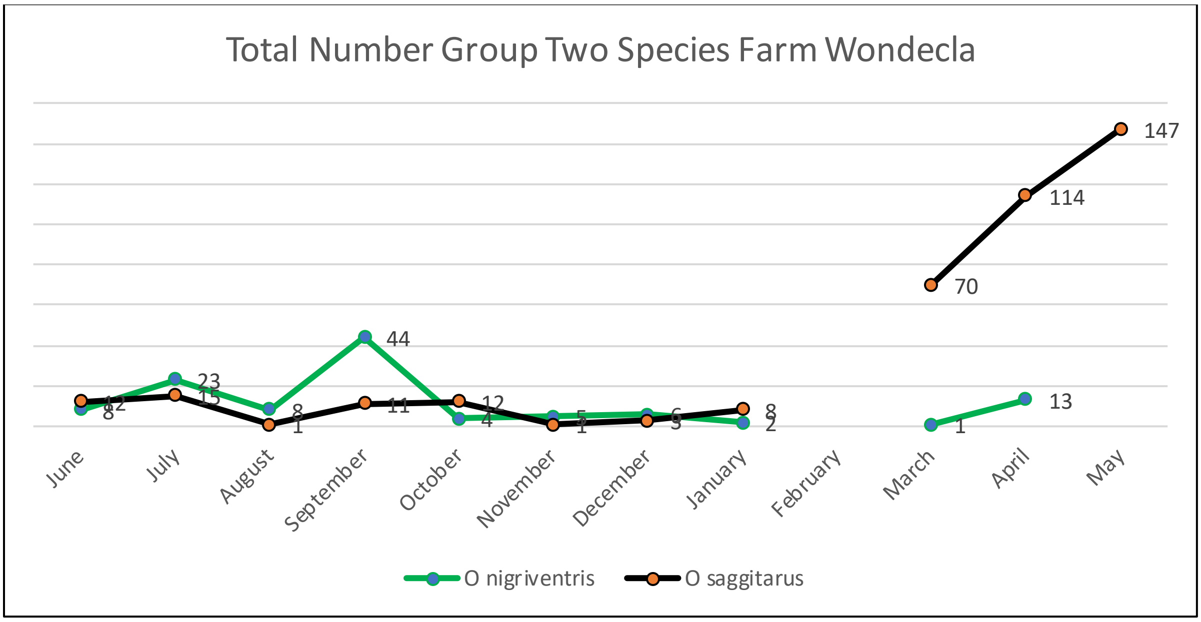


Figure 3: DBID-E total number of Group Two dung beetle species collected from Wondecla June 2021 – May 2022

Figure 4 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 and were similar to the DBID Project numbers. There were no more that 10 indviduals collected per month for these species and most beetles were collected in September (compared to the peak in November for the DBID Project).

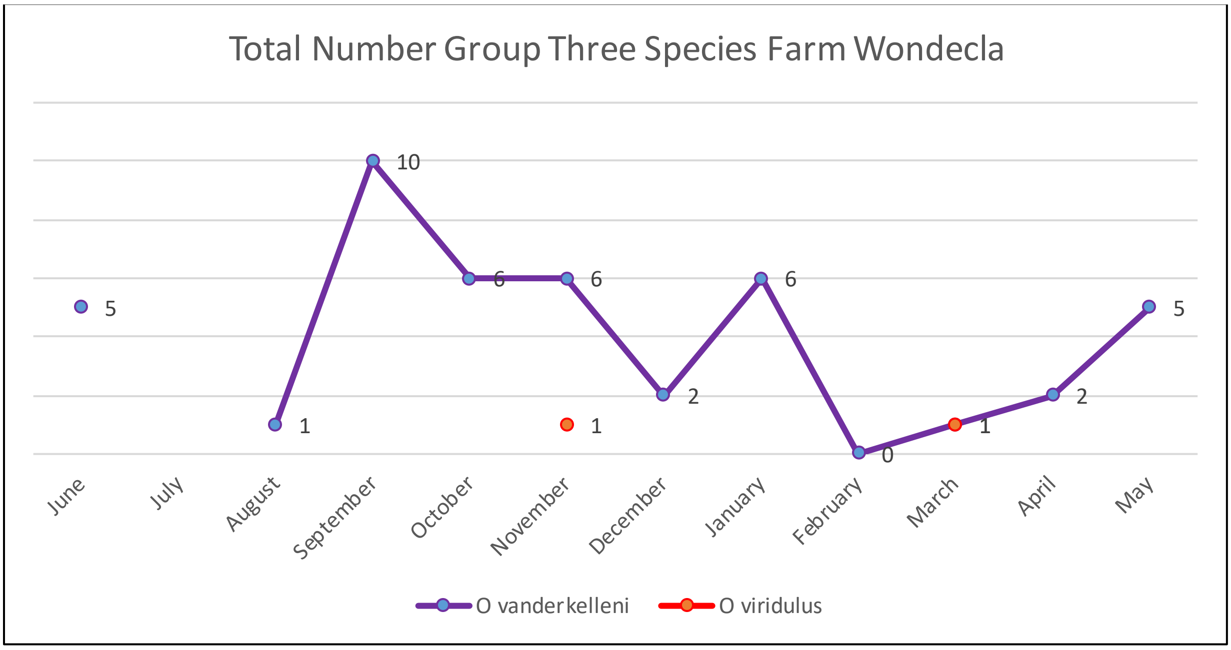


Figure 4: DBID-E total numbers of Group Three dung beetles collected from Wondecla June 2021 - May 2022

Numbers of *A lividus* identified were considerably lower than the previous DBID Project collections at this farm. There were two collections of *A fimetarius* but also in very low numbers (Figure 5).

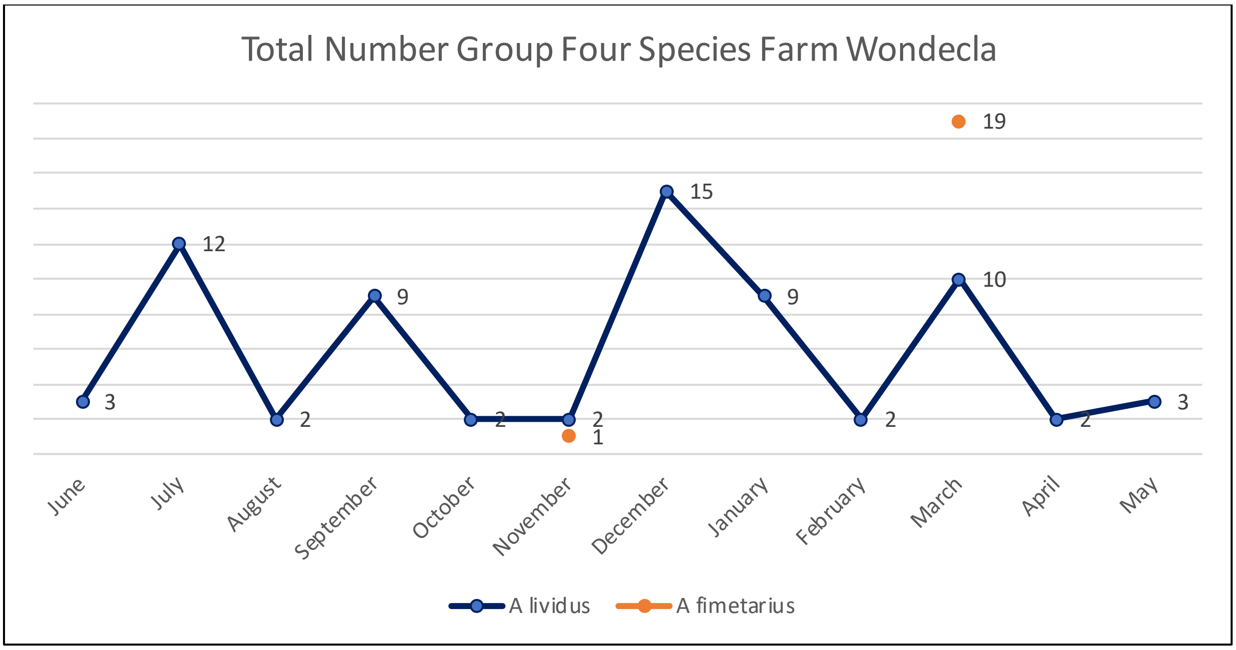


Figure 5: DBID-E total numbers of Group Four dung beetles collected from Wondecla June 2021 – May 2022

Figure 6 displays the peaks in abundance of Group Five dung beetles across the 12 month collection period at Farm Wondecla. Numbers were small for these two species but had increased from the DBID Project.

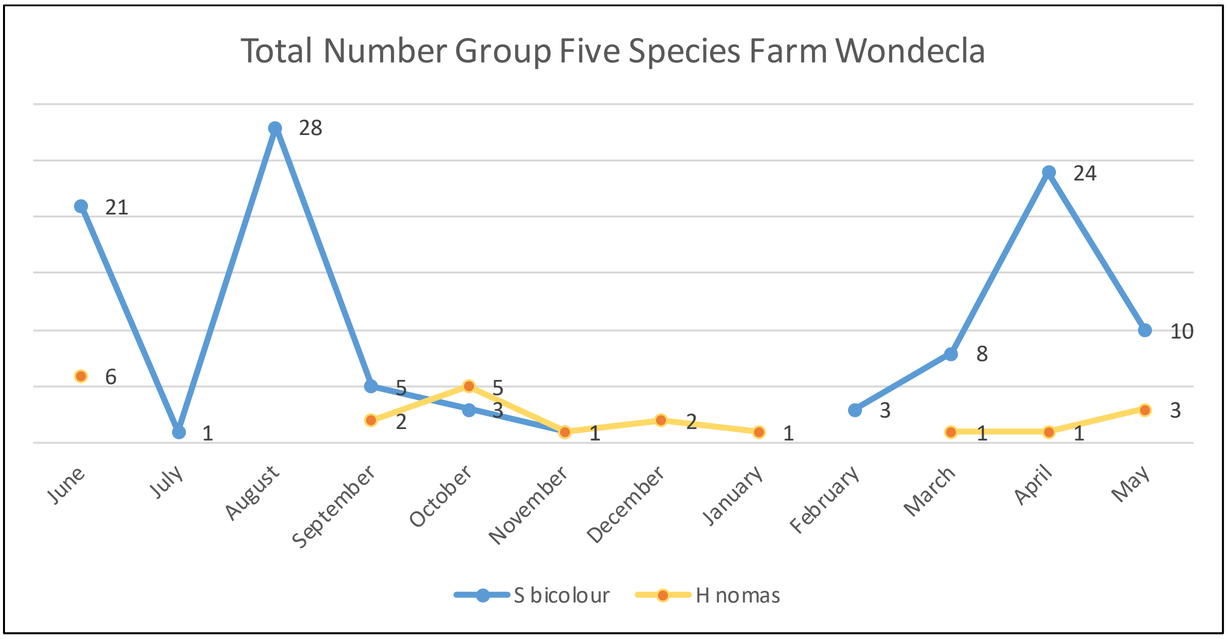


Figure 6: DBID-E total numbers of Group Five dung beetles collected from Wondecla June 2021 – May 2022

Farm PCG collected a variety of species and overall numbers were similar to the previous DBID Project, with peak activity from October to February. *O vanderkelleni* was again active on this property from October to December, however did not reach the previous peak of 20 specimens collected in the DBID Project. 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 either the DBID Project or the DBID-E Project. A species found on other DBID farms (*O viridulus*) was not collected from Farm PCG in either Project.

Table 9: DBID-E Project: Farm PCG monthly identification and abundance June 2021 – May 2022

Farm PCG	June	July	August	September	October	November	December	January	February	March	April	May
E intermedius									1		4	
L militaris									2			
D gazella					3	1	3	1	12			4
O nigriventris			2		1	2	2	2	3			
O saggitarus				2	2	7		1	12			
O vanderkelleni	3	6			1	8	1				1	
A lividus	10		3	3	83	40	100			3	10	34
A fimetarius		46						38				
S bicolour				5		1		5	11			
H nomas		9		5	9	4		4	2		1	1
TOTAL	**13**	**61**	**5**	**15**	**99**	**63**	**106**	**51**	**43**	**3**	**16**	**43**

Figure 7 displays the peaks in abundance of Group One dung beetles across the 12 month collection period at Farm PCG. There were significantly fewer specimens of L militaris collected (two) (Figure 7) compared to the previus project when 191 specimens were collected in April.

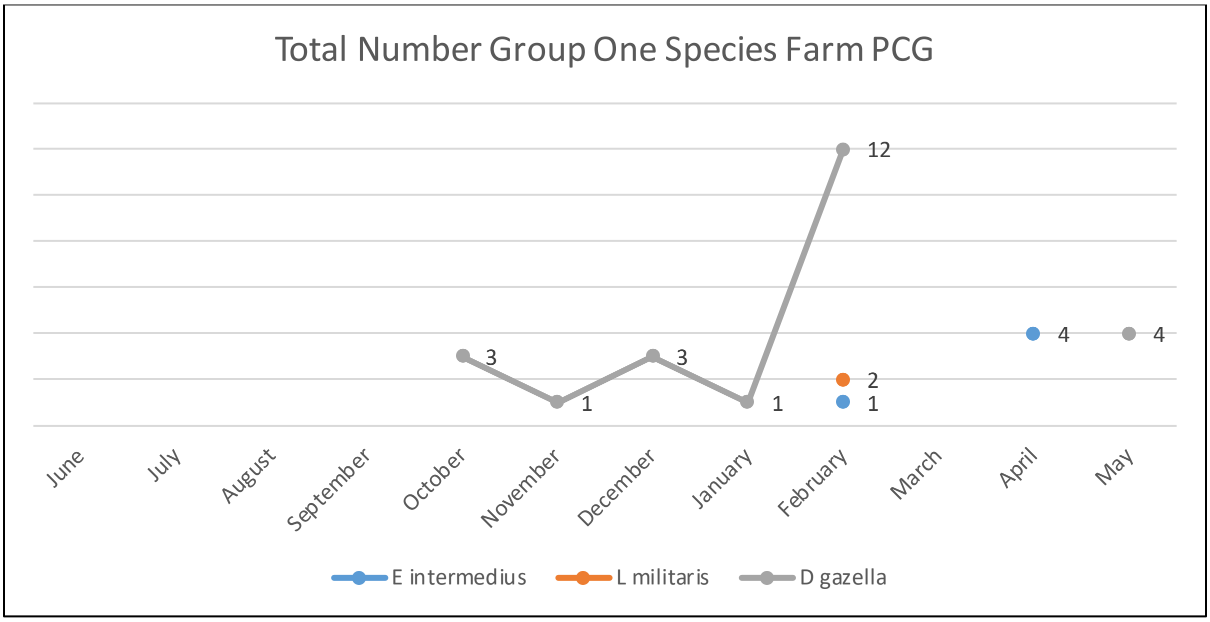


Figure 7: DBID-E total number of Group One dung beetle species collected from Farm PCG June 2021 – May 2022

Figure 8 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Farm PCG. Numbers were again very low, with specimens of the *O nigriventris* collected from October to February.

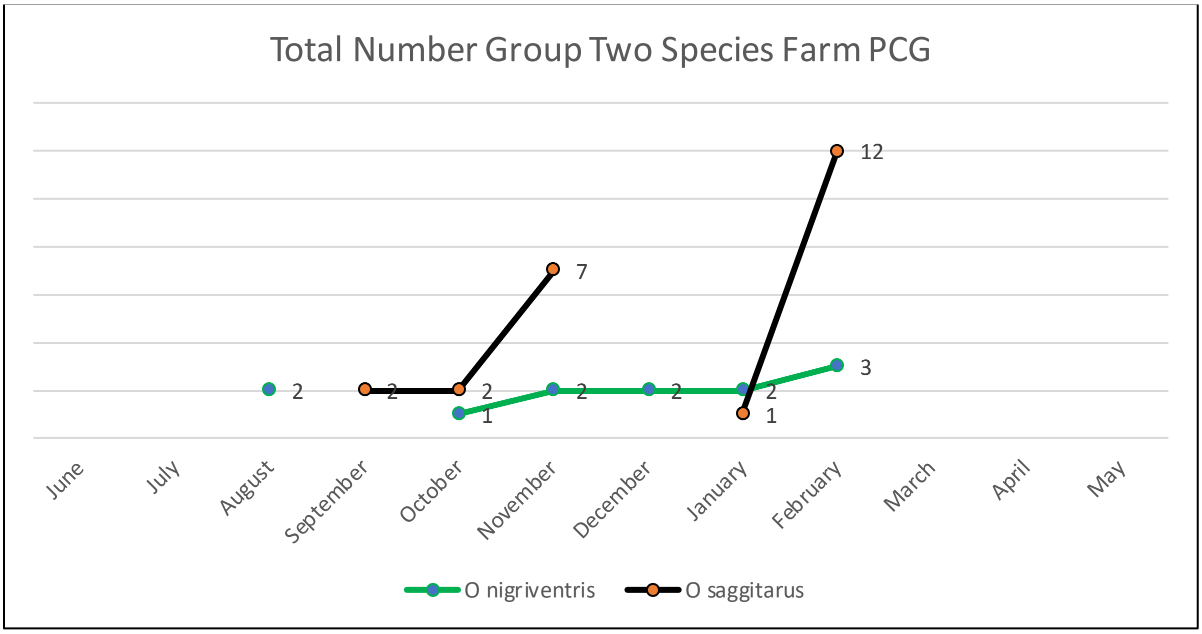


Figure 8: DBID-E total number of Group Two dung beetle species collected from Farm PCG June 2021 – May 2022

Figure 9 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 both July and November.

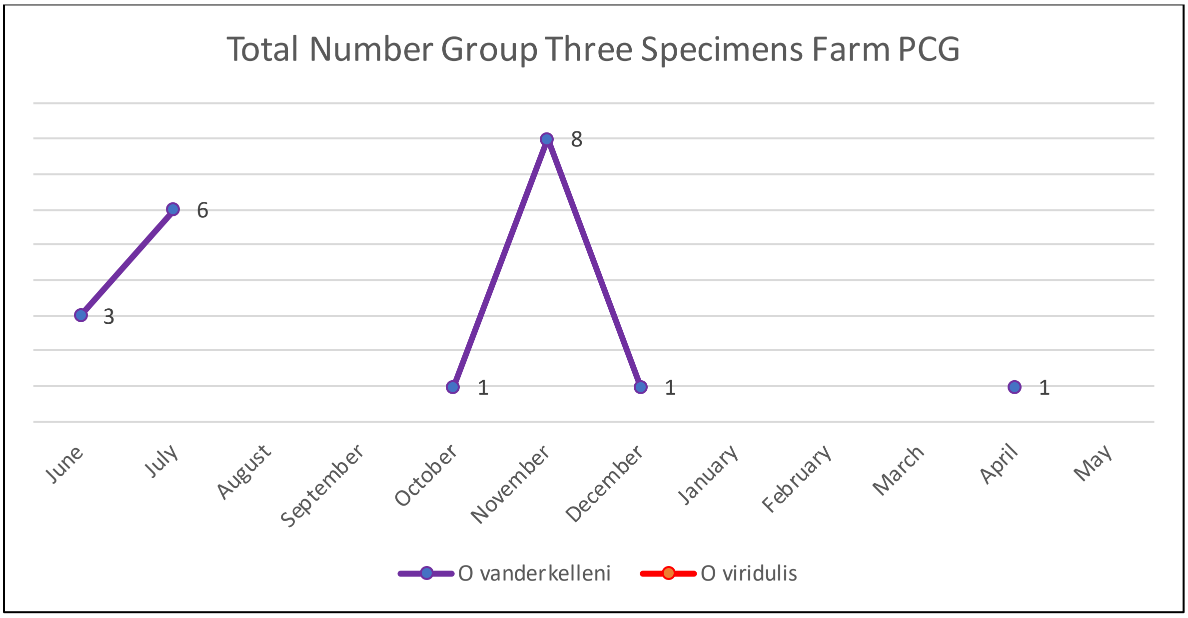


Figure 9: DBID-E total numbers of Group Three dung beetles collected from Farm PCG June 2021 – May 2022

Numbers of *A lividus* appeared to have two peaks during the year at this farm, over the October – December and April-May collection time points. There was only one observed peak in the DBID Project in March. *A lividus* was identified at nine collection points over the 12-month time period (Figure 10).

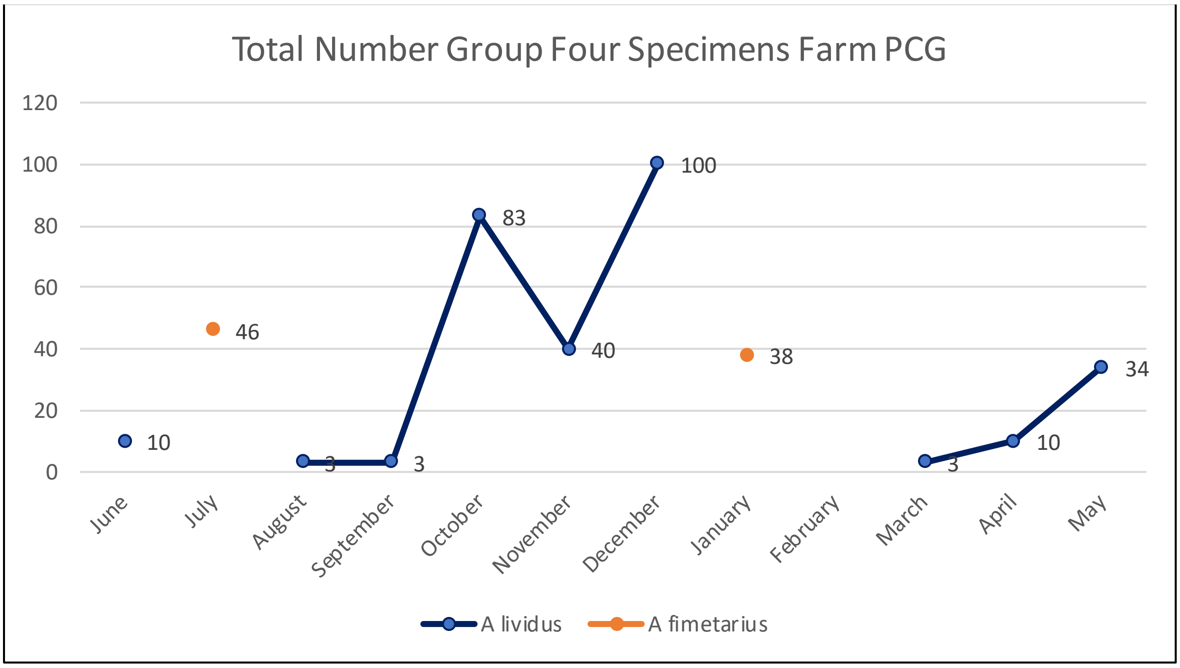


Figure 10: DBID-E total numbers of Group Four dung beetles collected from Farm PCG June 2021 – May 2022

Figure 11 displays the peaks in abundance of Group Five dung beetles across the 12 month collection period at Farm PCG. A small number of specimens of the *H nomas* were collected from this farm over most months of the year and *S bicolour* numbers peaked in February.

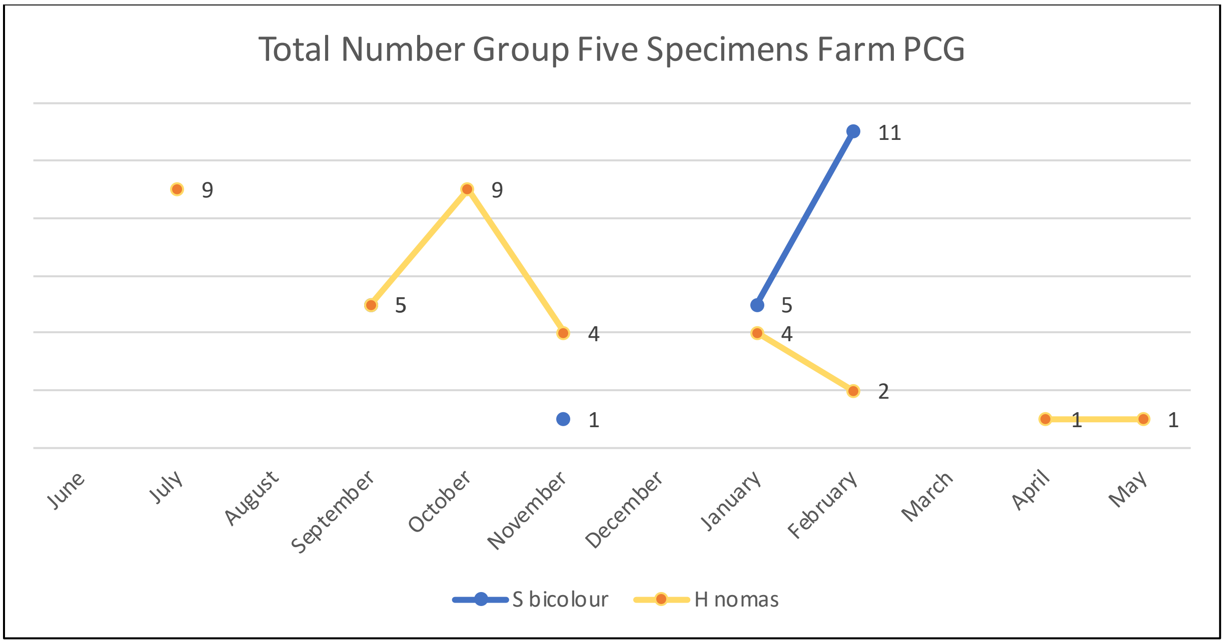


Figure 11: DBID-E total numbers of Group Five dung beetles collected from Farm PCG June 2021 – May 2022

Farm FTW This farm underwent stocking rate changes during the course of the project. Numbers of dung beetles at this farm were again very low and the dataset is incomplete for the 12 month collection timeframe. The most abundant and frequently collected beetle at Farm FTW was again the *A lividus* with the most specimens of this beetle collected in April (Table 10). The *O nigriventris* was not collected at any time on this farm during the two years of the DBID and DBID-E Projects despite being frequently found on other farms. Graphs are not provided here due to the low numbers and infrequent collections.

Table 10: DBID-E Project: Farm FTW monthly identification and abundance May 2020 – April 2021

FTW	June	July	August	September	October	November	December	January	February	March	April	May
E intermedius												
L militaris	2	1	2						1		1	
D gazella											9	
O saggitarus	1								1		4	
O vanderkelleni	1											
A lividus	1		1		1		29		3		40	
A spp2												
A fimetarius		2										
S bicolour									1		2	
H nomas	1	1					29		6		56	
TOTAL	**6**	**4**	**3**	**0**	**1**	**0**	**58**	**0**	**12**	**0**	**112**	**0**

Farm Biodynamic collected 10 different species of dung beetle, and while numbers generally were low of all identified species throughout the year (Table 11) there were more individual beetles collected than during the previous Project. The beetle *A fimetarius* had not been identified in the previous Project on this farm but was collected in March and April 2022. *O viridulus* was identified in the DBID Project but not collected at all during the 12 months collection period of the current Project. Peak activity in the DBID-E project occurred in November and April, compared to February and April in the previous Project.

Table 11: DBID-E Project: Farm Biodynamic monthly identification and abundance June 2021 – May 2022

FARM BIODYNAMIC	June	July	August	September	October	November	December	January	February	March	April	May
E intermedius	1				1							
L militaris	1					26		2			29	
D gazella				4	3	21	8	23			17	1
O nigriventris				2		21	1				8	
O saggitarus						1	1	1			5	
O vanderkelleni	6			4		6	1	3			4	
O viridulus												
A lividus	4			8		21	11	1		1	5	4
A fimetarius		3								2	1	
S bicolour	3	17				14	4	1			16	9
H nomas	10	2			3	10		1			6	1
TOTAL	**25**	**22**		**18**	**7**	**120**	**26**	**32**		**3**	**91**	**15**

Despite the introduction of dung beetle colonies in the MBPG Project in 2016 (*E intermedius* and *D gazella*), the abundance of these two species remains low and a single individual *E intermedius* was collected in June and October (Table 11, Figure 12).

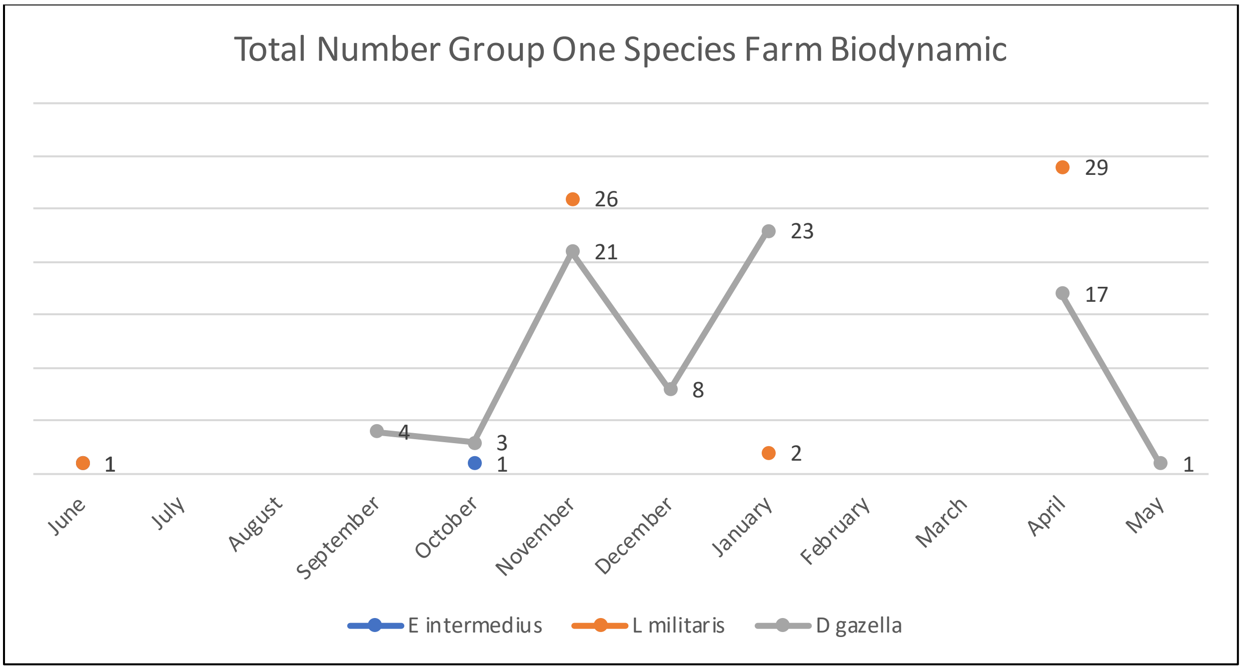


Figure 12: DBID-E total number of Group One dung beetle species collected from Farm Biodynamic June 2021 – May 2022

Figure 13 displays the peaks in abundance of Group Two dung beetles across the 12 month collection period at Farm Biodynamic. Numbers of these species were extremely low. O nigriventris was collected on three occassions September, November and April – all one month earlier than the previous Project, when a similar three month peak occurred (October, December and March).

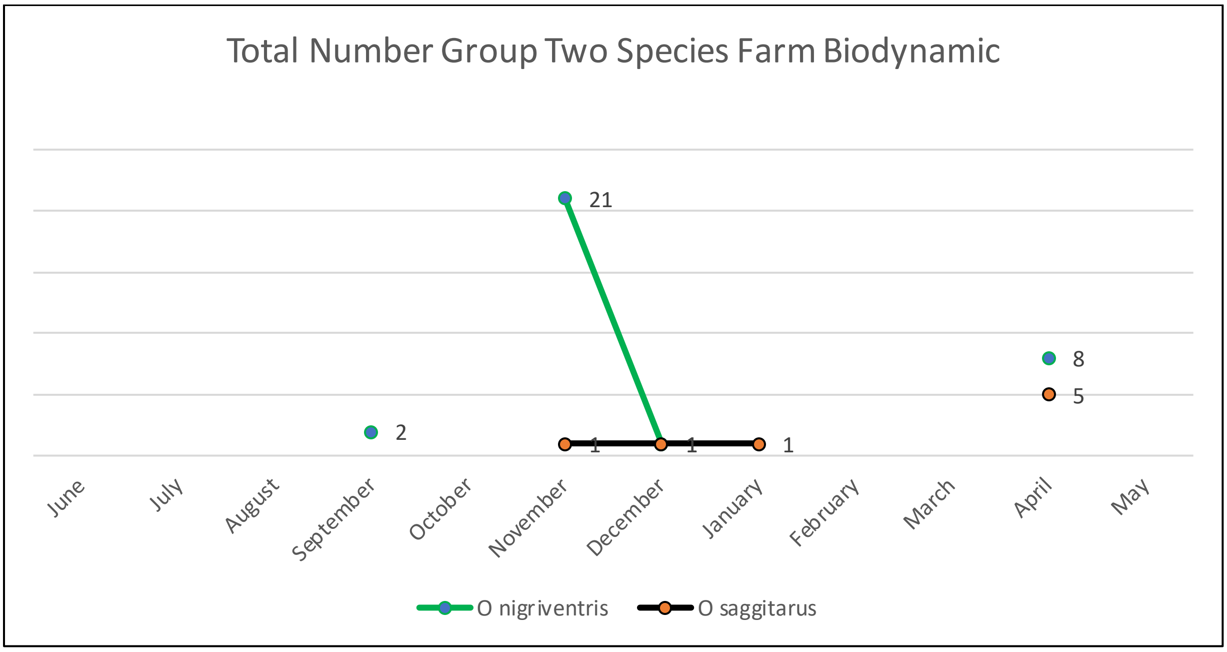


Figure 13: DBID-E total number of Group Two dung beetle species collected from Farm Biodynamic June 2021 – May 2022

Figure 14 displays the peaks in abundance of Group Three dung beetle species collected across the 12 month period at Farm Biodynamic. There were no O viridulus identifed in this Project and while very low (Figure 14), the number of O vanderkelleni collected was greater than in the previous Project.

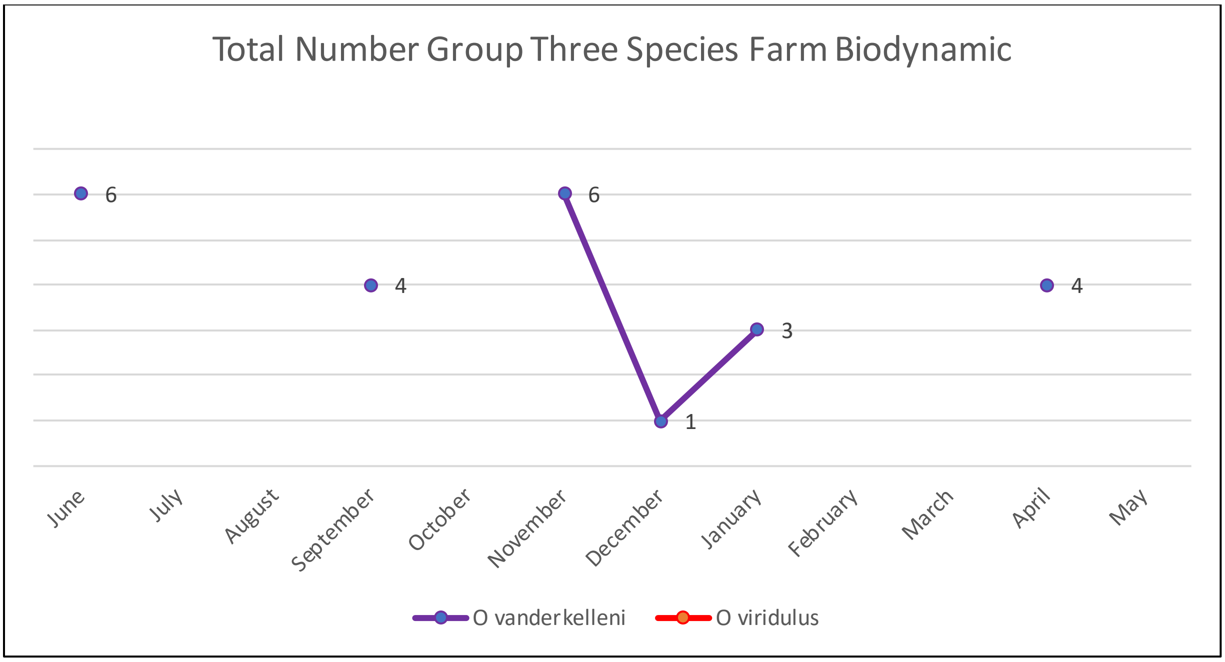


Figure 14: DBID-E total numbers of Group Three dung beetles collected from Farm Biodynamic June 2021 – May 2022

Figure 15 displays the peaks in abundance of Group Four and Five dung beetles across the 12 month collection period at Farm Biodynamic. Again, numbers of these species were small. The A fimetarius was found for the first time on this farm during the DBID-E Project at three collection points during the year (Figure 15). The *A lividus* was most active with the onset of the summer storms (November and December). Both *S bicolour* and *H nomas* were collected at multiple time points across the 12-month period.

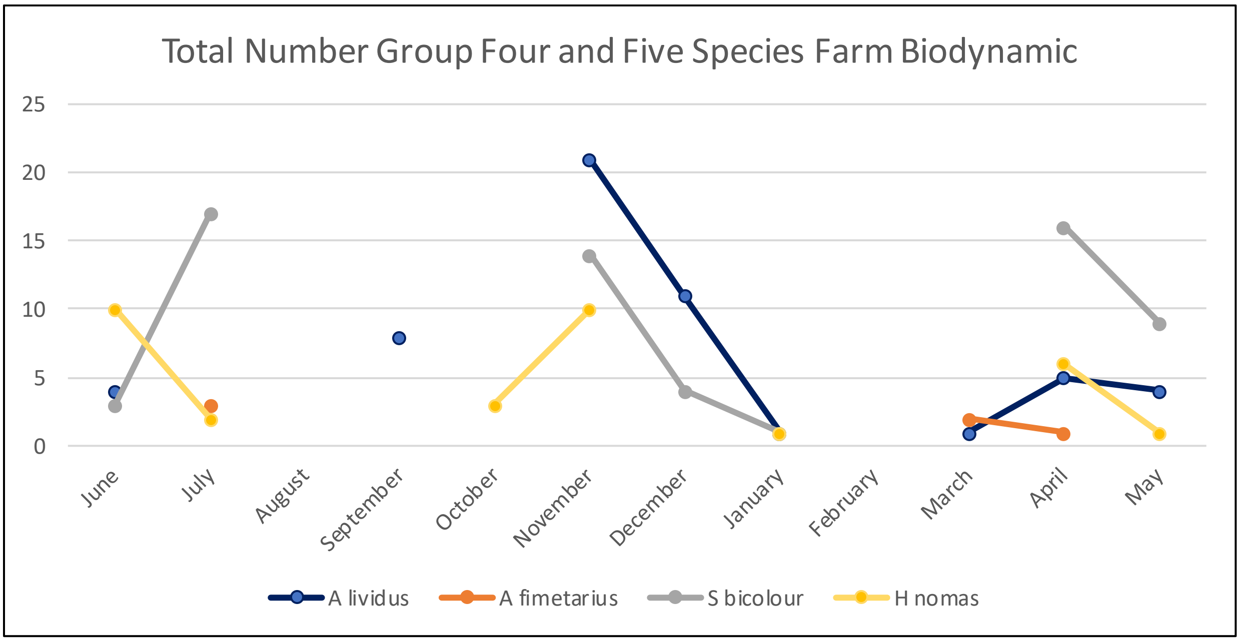


Figure 15: DBID-E total numbers of Group Four and Five dung beetles collected from Farm Biodynamic June 2021 – May 2022

Farm Platypus Creek During the DBID-E Project, there were 11 separate species of beetle identified (Table 12) and included confirmation of three species which had not previously been collected at this farm: *O viridulus, E intermedius and A fimetarius*. The number of beetles collected at this farm were significantly more compared to the previous Project at the same location. Peak activity of the dung beetles occurred with the onset of summer storms in November and December.

Table 12: DBID-E Project: Farm Platypus Creek monthly identification and abundance June 2021 – May 2022

PLATYPUS	June	July	August	September	October	November	December	January	February	March	April	May
E intermedius	1	1					3	7				
L militaris								1				
D gazella						10	14	8	13	4	4	1
O nigriventris		4						2			1	9
O sagittarius		1				3		3	9			1
O vanderkelleni		2	4	9	5	1	19	4	5	4	6	
O viridulus						2						
A lividus	15			3	8	4	22	1	3		2	
A fimetarius						15			14			
S bicolour	7	7	2	2	2	7	1	17	11	40	10	12
H nomas	1	4	11	6	8	2	4	2	3	5	9	2
TOTAL	**24**	**19**	**17**	**20**	**23**	**44**	**63**	**45**	**58**	**53**	**32**	**25**

Figure 16 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 low across the 12 month period with only a single beetle of the *L militaris* collected in the entire year. However, the total number of *D gazella* specimens identifed was nearly trebled compared to the previous Project.

Specimens of the *E intermdius* species were identifed at four collectiomn time points in this Project - compared to none at all in the DBID Project.

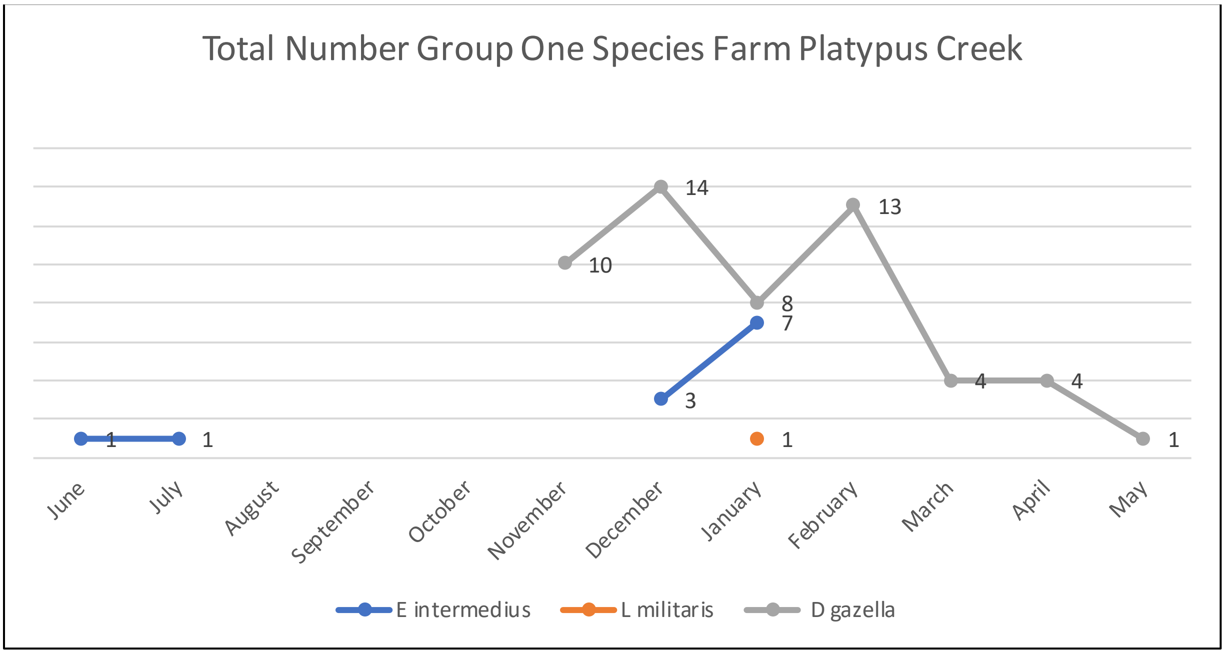


Figure 16: DBID-E total number of Group One dung beetle species collected from Platypus Creek June 2021 – May 2022

Figure 17 displays the peaks in abundance of Group Two and Three species of dung beetles across the 12 month collection period at Platypus Creek. Two *O viridulus* specimens were identified for the first time at this farm in November, and *O vanderkelleni* was identified in almost every month of the year.

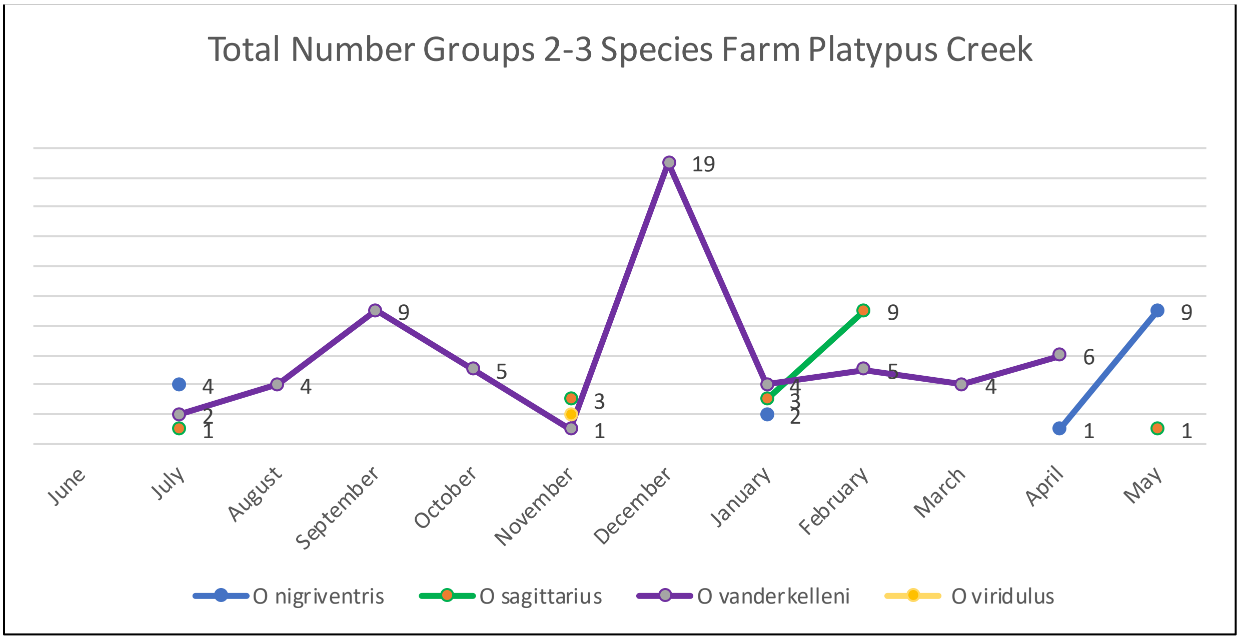


Figure 17: DBID-E total number of Group 2-3 dung beetle species collected from Platypus Creek June 2021 – May 2022

Figure 18 displays the peaks in abundance of Group Four species of dung beetles across the 12 month collection period at Platypus Creek. Specimens of A fimetarius were identified for the first time at his farm at two time points during the year. Numbers of A lividus increased slightly over the year compared to the previous year at this farm.

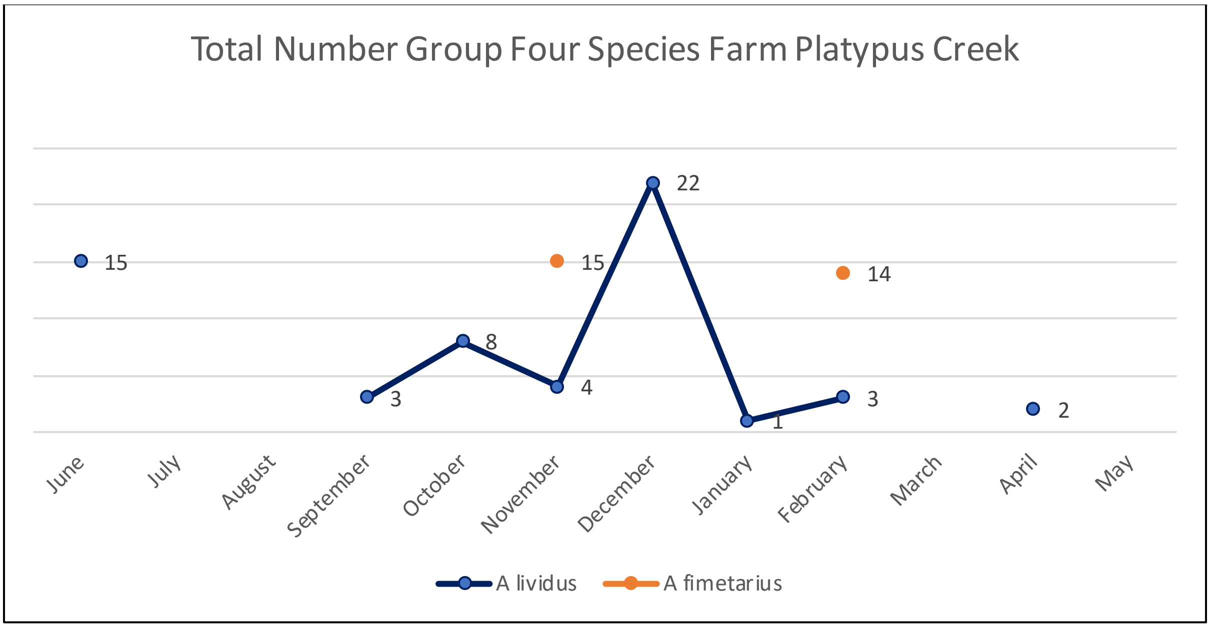


Figure 18: DBID-E total number of Group Four dung beetle species collected from Platypus Creek June 2021 – May 2022

Figure 19 displays the peaks in abundance of Group Five species of dung beetles across the 12 month collection period at Platypus Creek. Specimens of this group were collected throughpu t the year with a peak in March of the *S bicolour*.

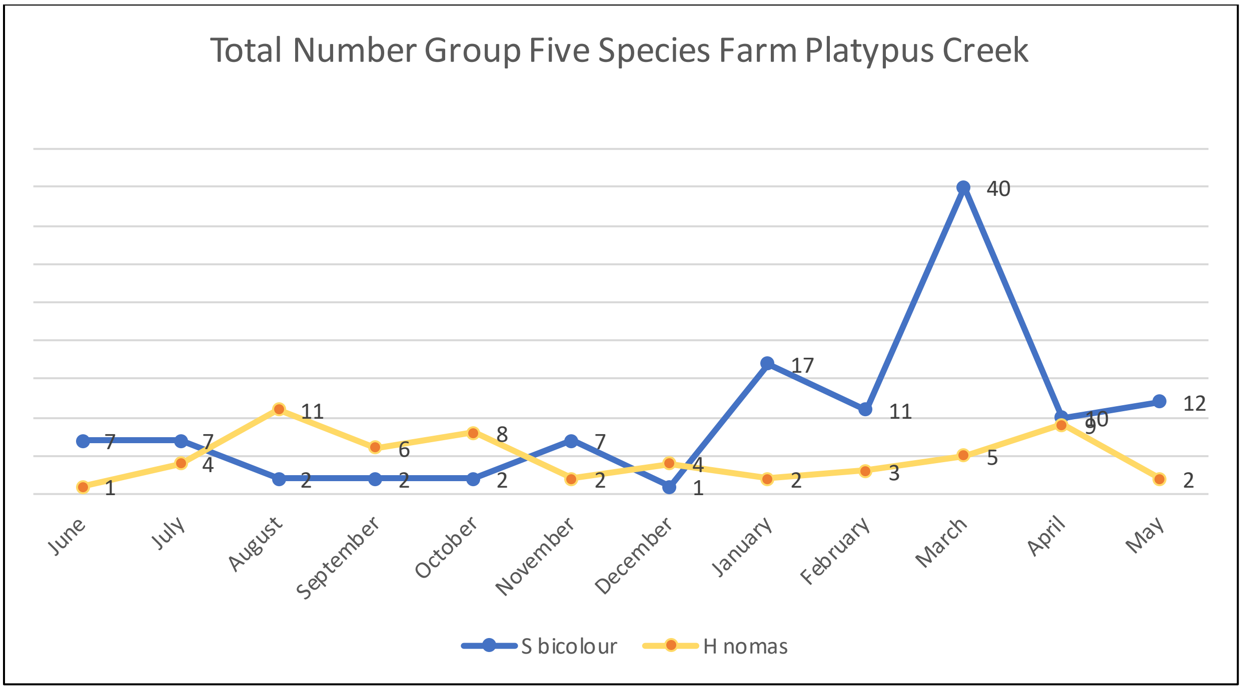


Figure 19: DBID-E total number of Group Five dung beetle species collected from Platypus Creek June 2021 – May 2022

Farm Specific Dung Beetle Identification: the new farms

Due to the incompleteness of the data – we report the identifications in detail on four of the new farms and provide a summary of the remaining farms.

Farm CedarValley There were 10 separate species of beetle identified with most activity seen November – January (Table 13). Individuals of the *O vanderkelleni* were identified at seven collection points during the year, however there were no specimens of *O viridulus* identified at this farm.

Table 13: DBID-E Project: Farm CedarValley monthly identification and abundance June 2021 – May 2022

	June	July	August	Sept	October	Nov	Dec	Jan	Feb	Mar	Apr	May
E intermedius					5	7	1	24		1		
L militaris	2	4		1		4				1		
D gazella		1			1	5	4	18	4	5		
O nigriventris		17			2	5		18	1			
O saggitarus		1				2		3		2		6
O vanderkelleni	10	10	4	1	2	11		23				
A lividus						68	200		12	41		
A fimetarius									13			1
S bicolour		6		6				34	7	2		
H nomas	5	6	1	1	4	7		4	5			
TOTAL	**17**	**45**	**5**	**9**	**14**	**109**	**204**	**124**	**42**	**52**		**7**

Figure 20 displays the peaks in abundance of Group One species of dung beetles across the 12 month collection period at Farm CedarValley. The peak of the *E intermedius* and *D gazella* occurred in January. Numbers of *L militaris* were extremely low.

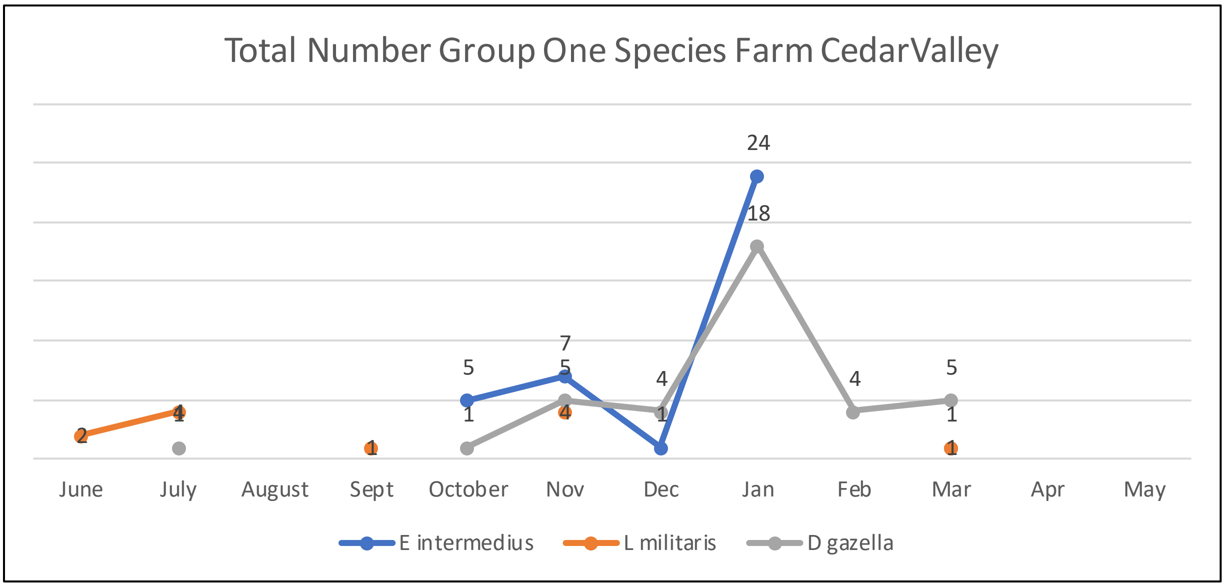


Figure 20: DBID-E total number of Group One dung beetle species collected Farm CedarValley June 2021 – May 2022

Figure 21 displays the peaks in abundance of Group Two species of dung beetles across the 12 month collection period at Farm CedarValley. There were two distinct peaks of activity at this farm (July and January) for the *O nigriventris*.

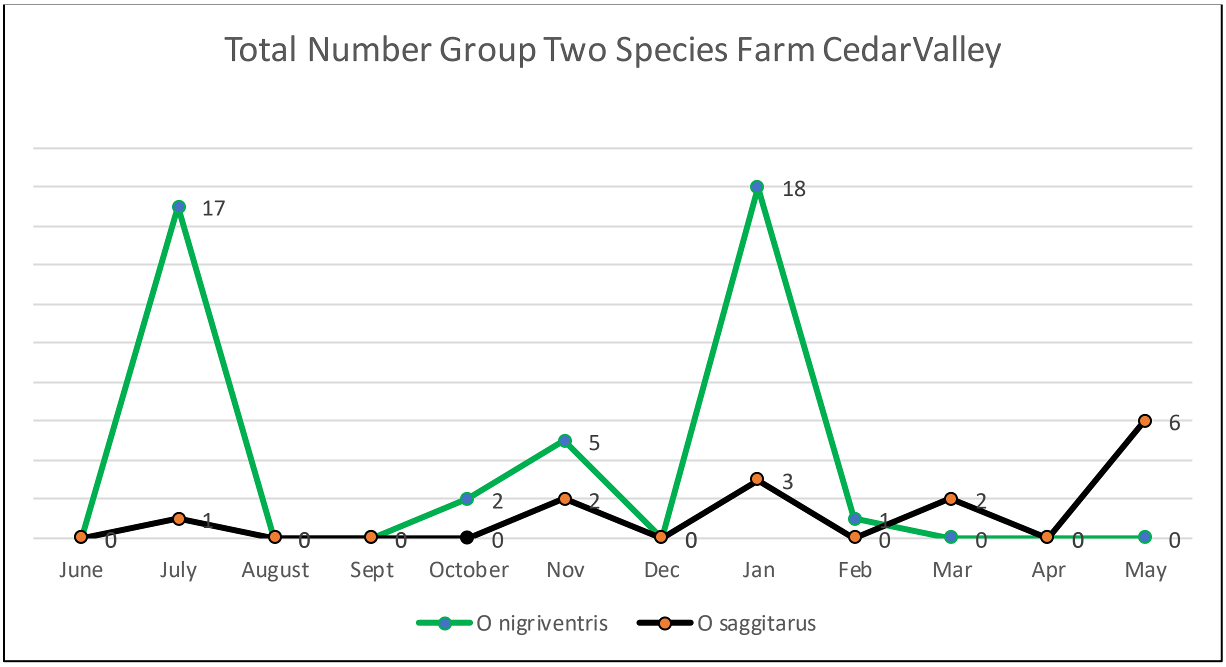


Figure 21: DBID-E total number of Group Two dung beetle species collected Farm CedarValley June 2021 – May 2022

Figure 22 displays the peaks in abundance of Group Three species of dung beetles across the 12 month collection period at Farm CedarValley. The *O vanderkelleni* was most active June – January, however there were no speicmens collected in December, despite being active at this farm in the month before and after. There were no speicmens of *O viridulus* identified at this farm.

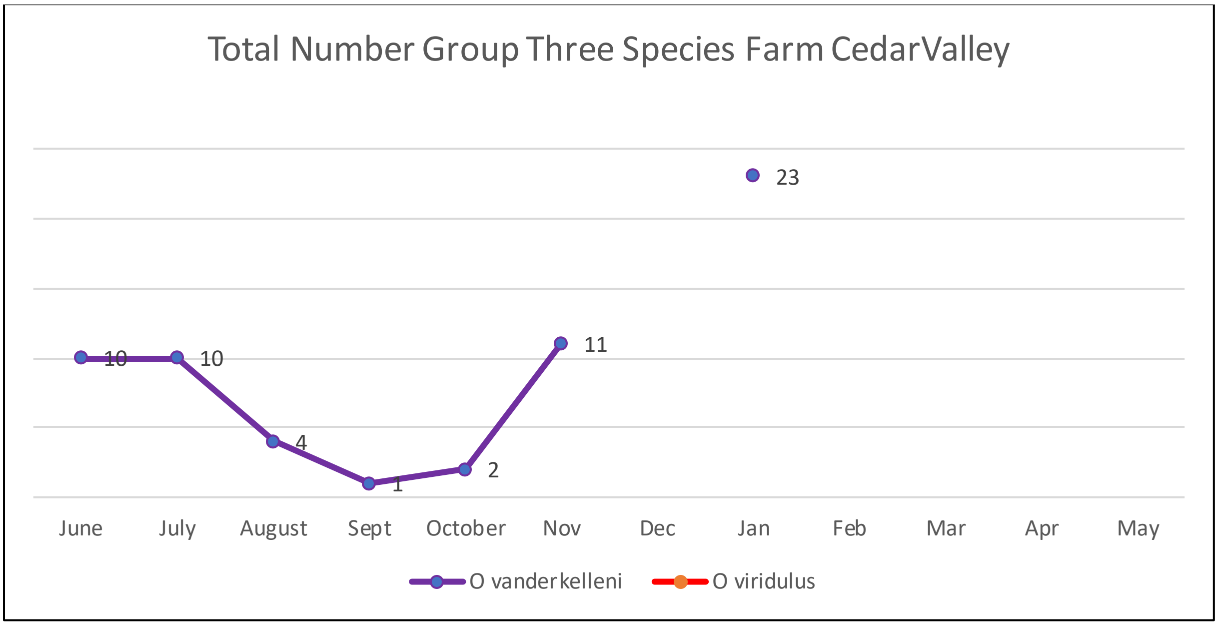


Figure 22: DBID-E total number of Group Three dung beetle species collected Farm CedarValley June 2021 – May 2022

Figure 23 displays the peaks in abundance of Group Four species of dung beetles across the 12 month collection period at Farm CedarValley. There were two peaks in activity of the A lividus in November and March at this farm. Numbers of A fimetarius were low and only collected at two time points during the year (February and May).

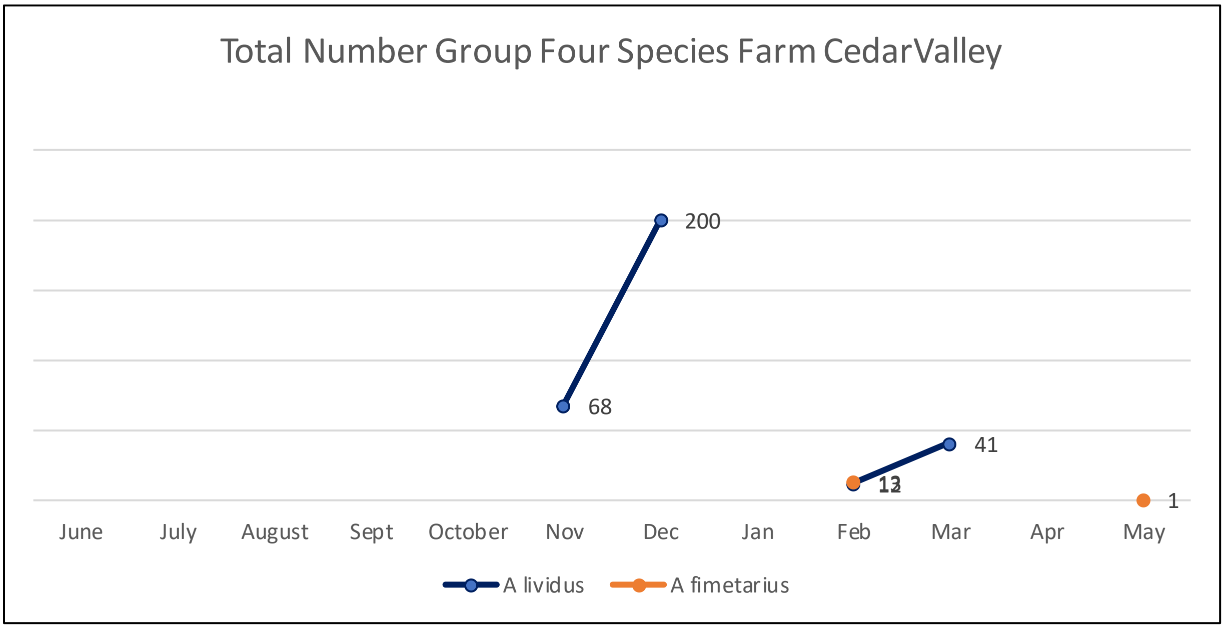


Figure 23: DBID-E total number of Group Four dung beetle species collected Farm CedarValley June 2021 – May 2022

Figure 24 displays the peaks in abundance of Group Five species of dung beetles across the 12 month collection period at Farm CedarValley. The *H nomas* was active during the winter months but in very low numbers, and there was a peak of the *S bicolour* activity in January.

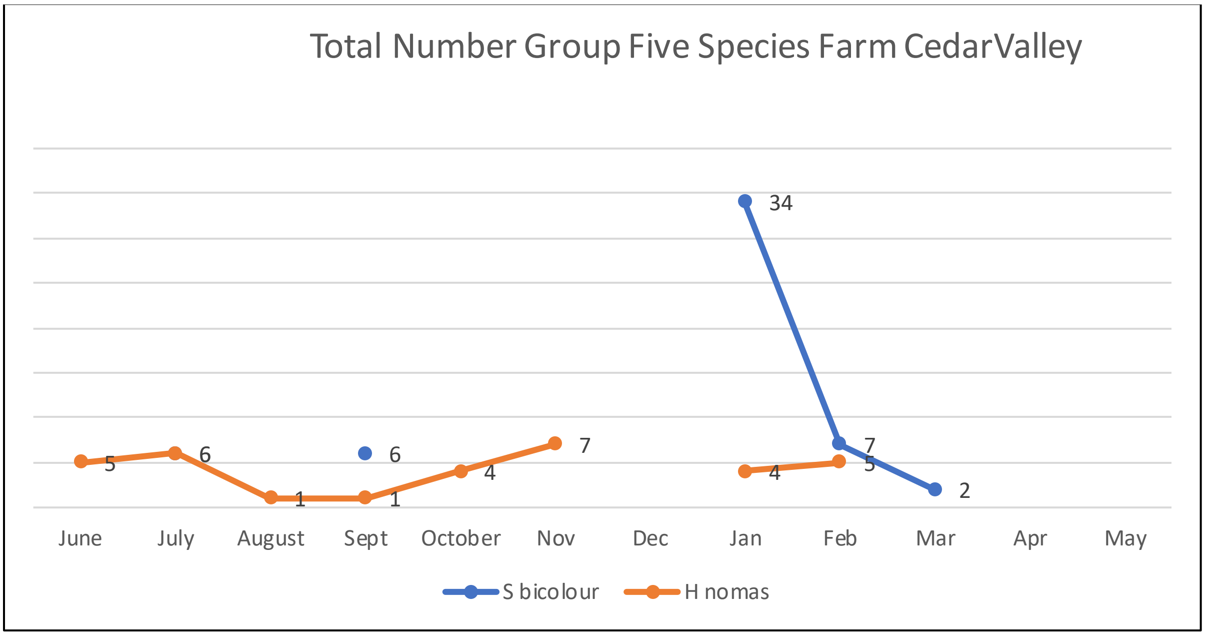


Figure 24: DBID-E total number of Group Five dung beetle species collected Farm CedarValley June 2021 – May 2022

Farm Cadaghi There were 11 separate species of beetle identified with most activity seen December – June (Table 14). Numbers of beetles collected were generally greater than most other farms during the year, including 850 individual specimens of *L militaris* collected in December. Three species were collected at each collection point in the year: *E intermedius, L militaris and O saggitarus.* Unfortunately, the identification of the February sample was not recorded. However, the owner maintained a record of the number of beetles sent and an approximation of the species. Based on the photos we can assume the same species as January were present (and as for Farm Wondecla).

Table 14: DBID-E Project: Farm Cadaghi monthly identification and abundance June 2021 – May 2022

	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
E intermedius	57	3	3	15	46	14	29	45		52	32	3
L militaris	17	16	1	7	10	13	850	81		30	2	95
D gazella	5	4			6	12	43	325		101	58	10
O nigriventris	3	1		1	10	3	80	2		20		1
O saggitarus	19	2	1	5	24	5	9	10		39	67	33
O vanderkelleni				1	12		8			2	10	7
O viridulus					3	1						1
A lividus	32		2				5	4	50	12	12	3
A fimetarius		19								7	9	
S bicolour	39	1	2	7	5				20	26	83	2
H nomas	1	6	1	11	3		1		10		4	2
TOTAL	**173**	**52**	**10**	**47**	**120**	**48**	**1025**	**467**	**202**	**289**	**277**	**157**

Figure 25 displays the peaks in abundance of Group One species of dung beetles across the 12 month collection period at Farm Cadaghi. Due to the scale obsuring the data, Figure 25B displays the same information but without the 850 December L militaris data. This group of species were active through out the year and in good numbers compared to most other farms.

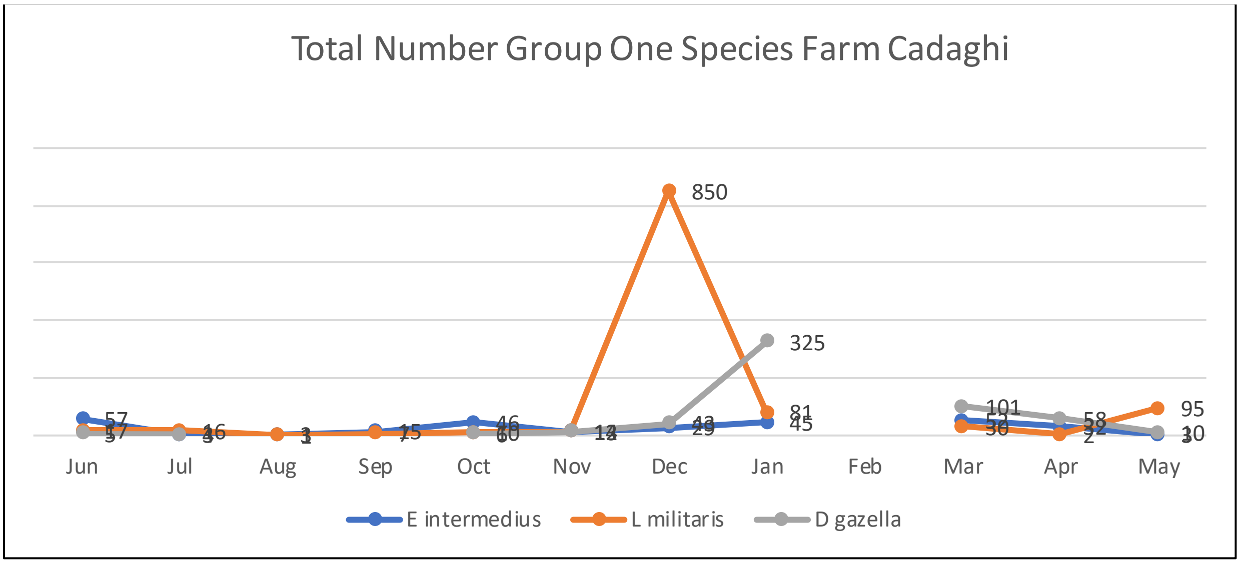


Figure 25: DBID-E total number of Group One dung beetle species collected Farm Cadaghi June 2021 – May 2022

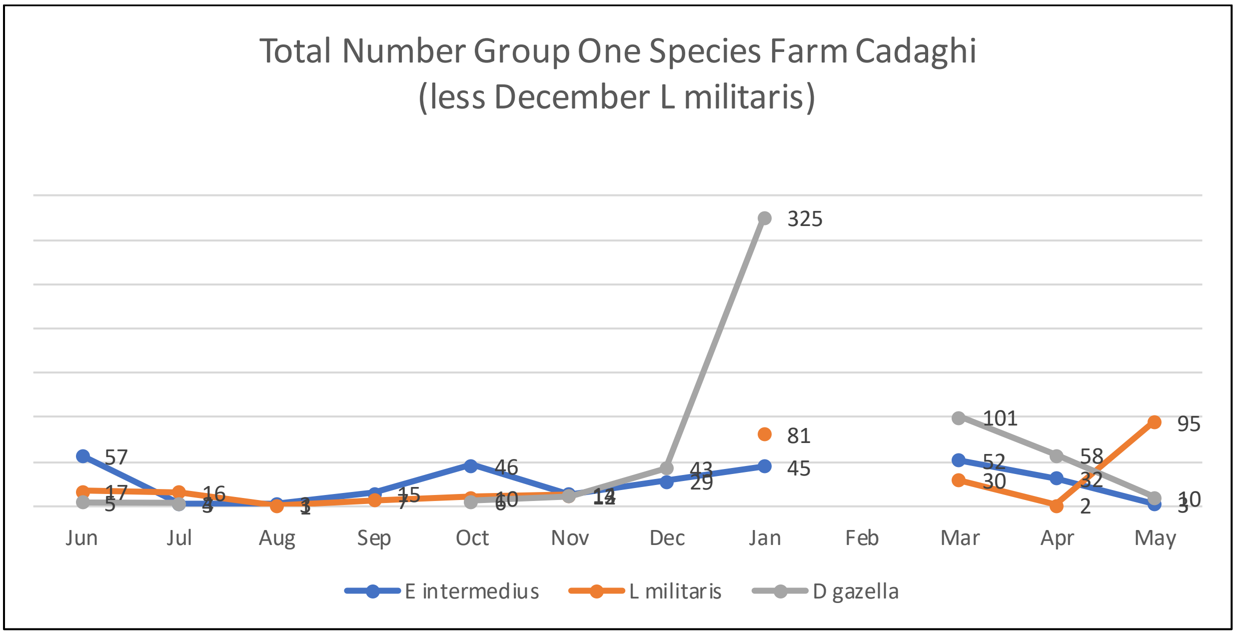


Figure 25B: DBID-E total number of Group One dung beetle species collected Farm Cadaghi (less *L militaris* December) June 2021 – May 2022

Figure 26 displays the peaks in abundance of Group Two species of dung beetles across the 12 month collection period at Farm Cadaghi. Peak activity of the O nigriventris was in December and in April for the O saggitarus.

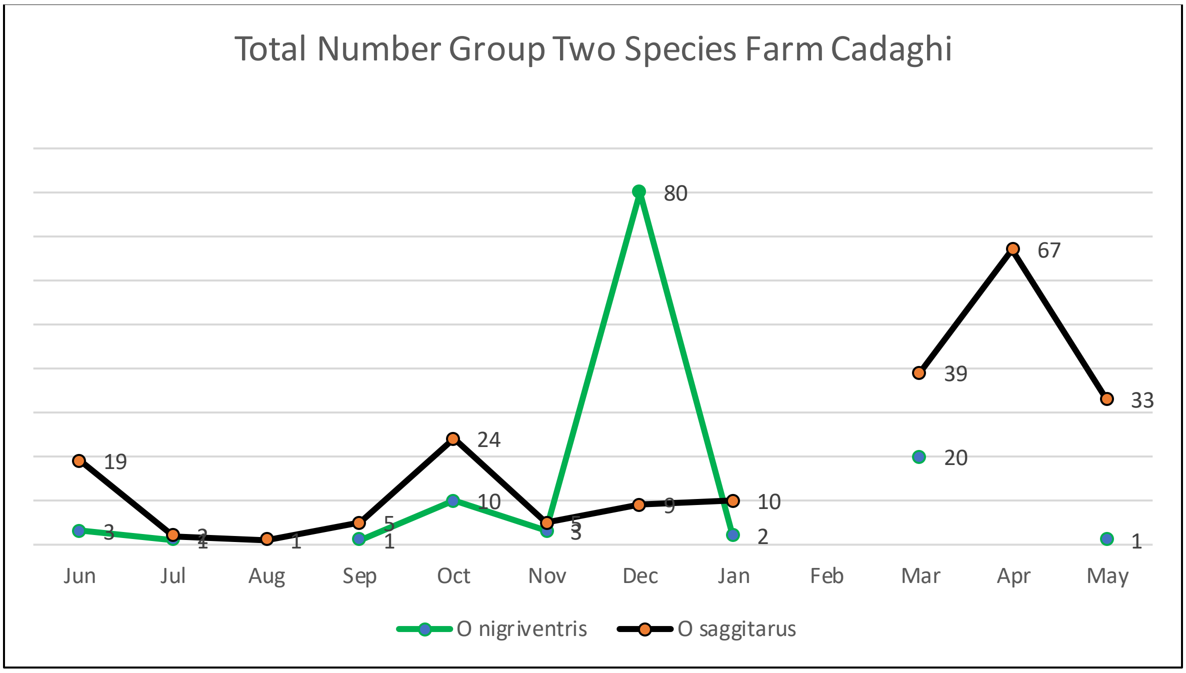


Figure 26: DBID-E total number of Group Two dung beetle species collected Farm Cadaghi June 2021 – May 2022

Figure 27 displays the peaks in abundance of Group Three species of dung beetles across the 12 month collection period at Farm Cadaghi. Peak activity of *O vanderkelleni* occurred in October and April. Specimens of *O viridulus* were identifed on this farm at three time points during the year.

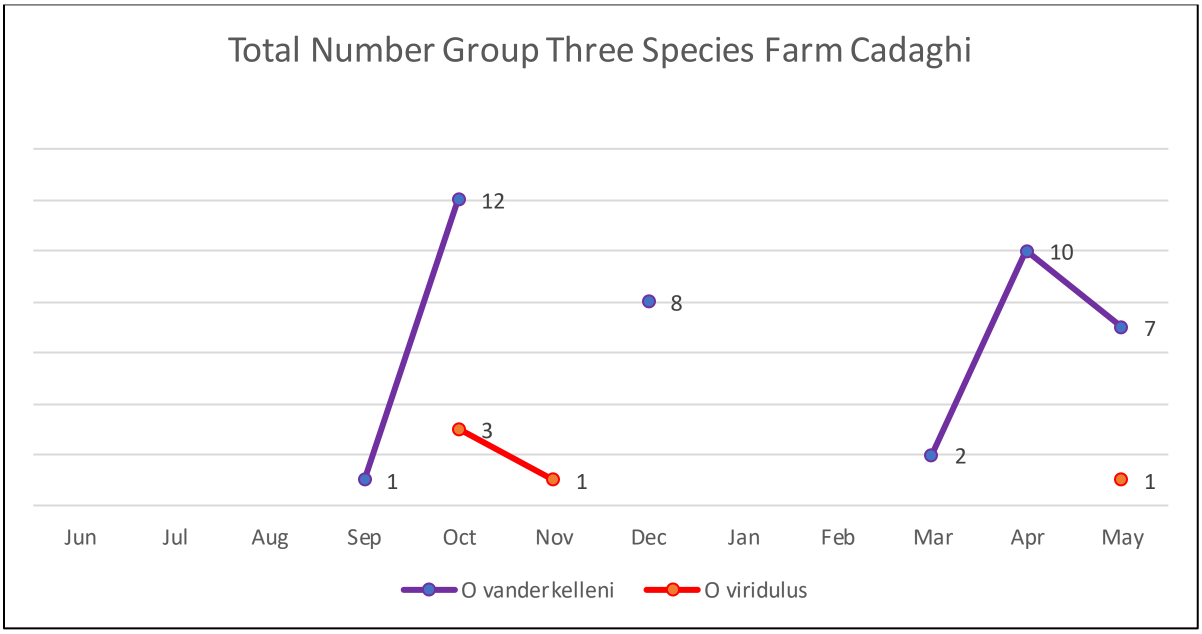


Figure 27: DBID-E total number of Group Three dung beetle species collected Farm Cadaghi June 2021 – May 2022

Figure 28 displays the peaks in abundance of Group Four species of dung beetles across the 12 month collection period at Farm Cadaghi. Specimens of *A lividus* were found in most months of the year but in low numbers.

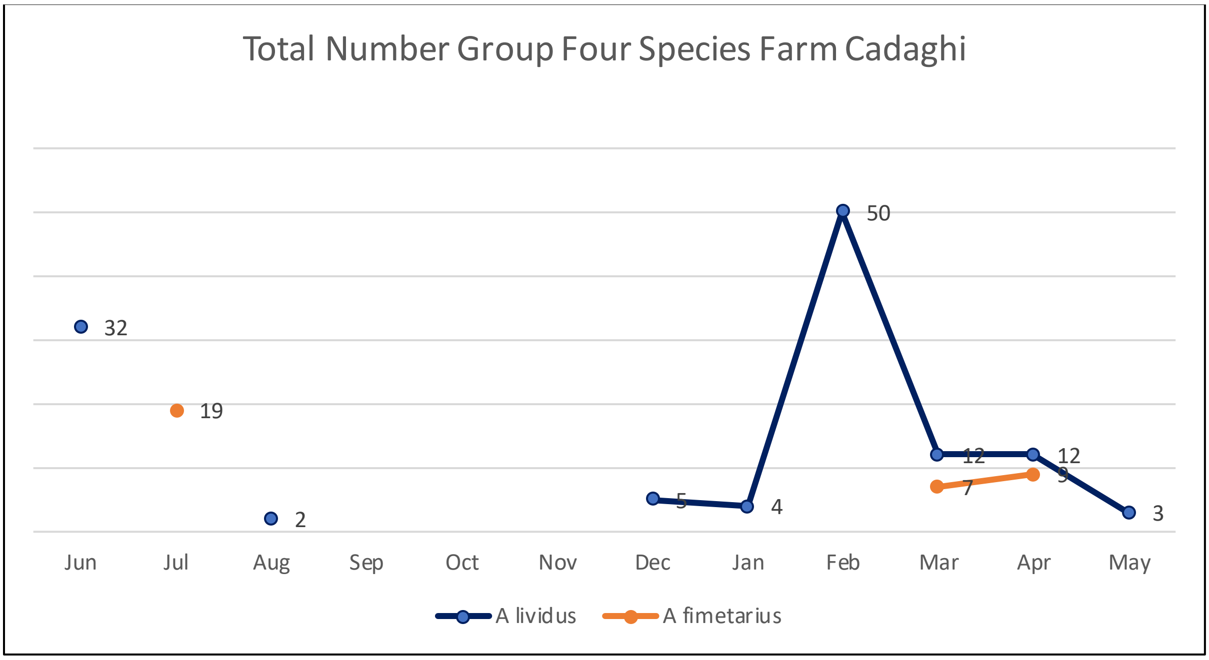


Figure 28: DBID-E total number of Group Four dung beetle species collected Farm Cadaghi June 2021 – May 2022

Figure 29 displays the peaks in abundance of Group Five species of dung beetles across the 12 month collection period at Farm Cadaghi. Both species were collected throughout most months of the year with a peak in April of the *S bicolour*.

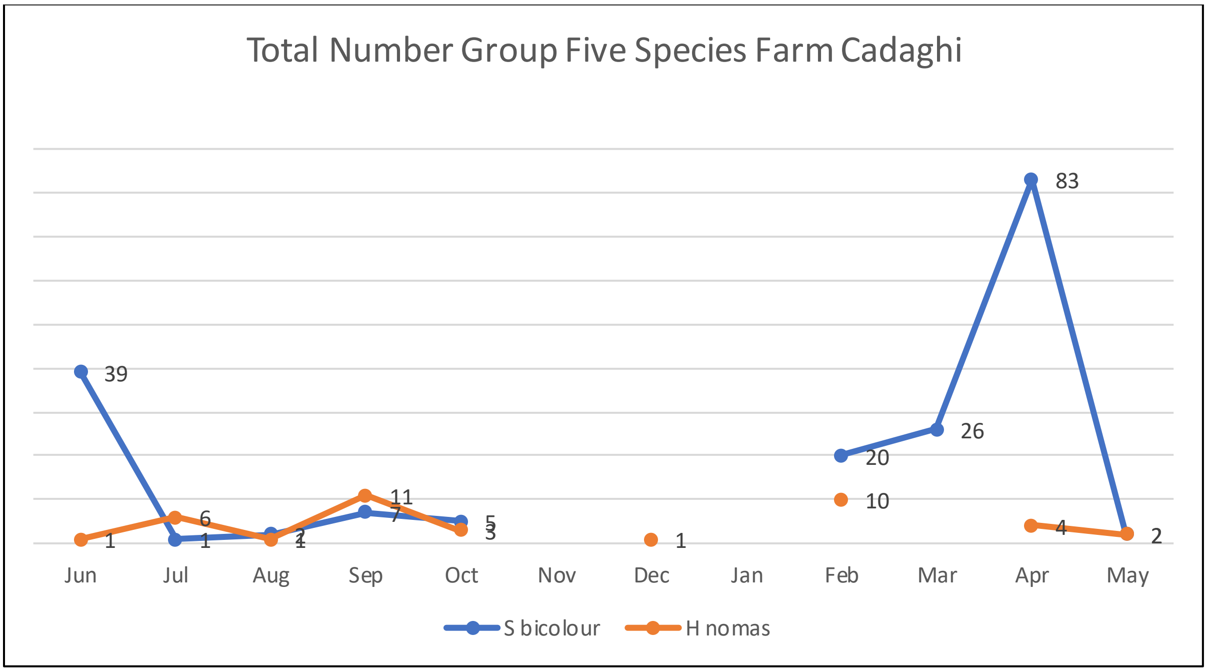


Figure 29: DBID-E total number of Group Five dung beetle species collected Farm Cadaghi June 2021 – May 2022

Farm Barefoot There were 10 separate species of beetle identified on this farm with most activity seen November – April (Table 15). Numbers of O vanderkelleni were large compared to other farms and both this species and the O nigriventris were found at this farm throughout the year.

Table 15: DBID-E Project: Farm Barefoot monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
E intermedius	20		1			9	6	13	1		5	
L militaris	13											1
D gazella						3	7	13	4	2	7	6
O nigriventris	2	3	27		5	8	19	15	27	17	15	5
O saggitarus	2							2		1	3	3
O vanderkelleni	4	4	2		6	46	22	18	29	4	7	43
A lividus							15			1	2	
A fimetarius												
S bicolour	5	1	1					4	1	40	133	1
H nomas	1	1	1		2	22	2	2	1	4	10	
TOTAL	**47**	**9**	**32**		**13**	**88**	**71**	**67**	**63**	**69**	**182**	**59**

Figure 30 displays the peaks in abundance of Group One species of dung beetles across the 12 month collection period at Farm Barefoot. Peak activity for this group was November to February with another larger peak in June for *E intermedius* and *L militaris*.

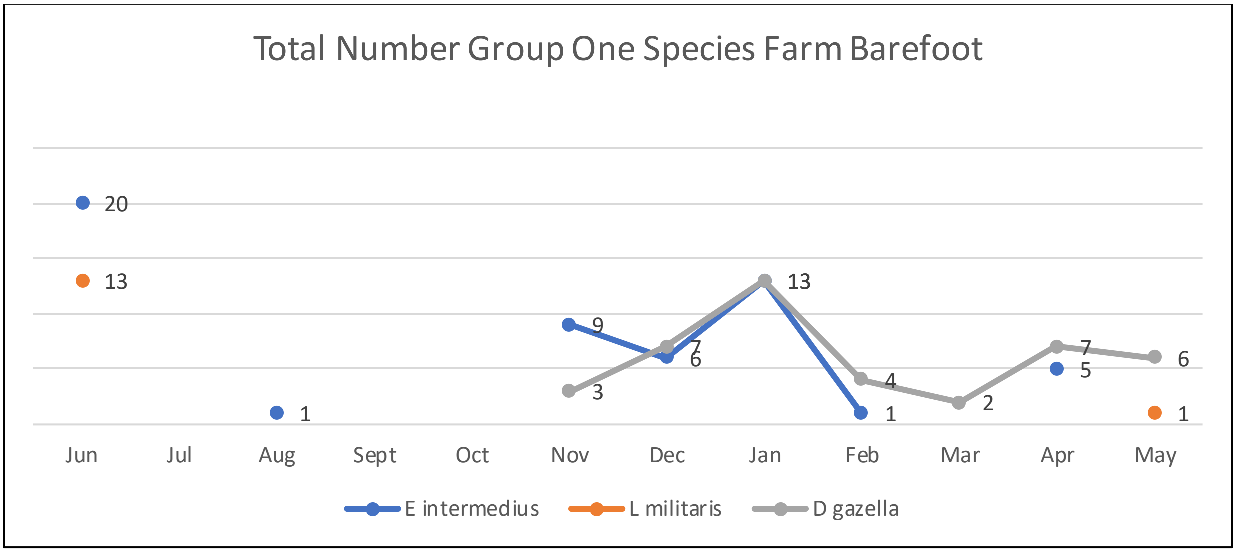


Figure 30: DBID-E total number of Group One dung beetle species collected Farm Barefoot June 2021 – May 2022

Figure 31 displays the peaks in abundance of Group Two species of dung beetles across the 12 month collection period at Farm Barefoot. Numbers of *O nigriventris* were realtively high compared to other farms and this species was collected in most months of the year at this farm.

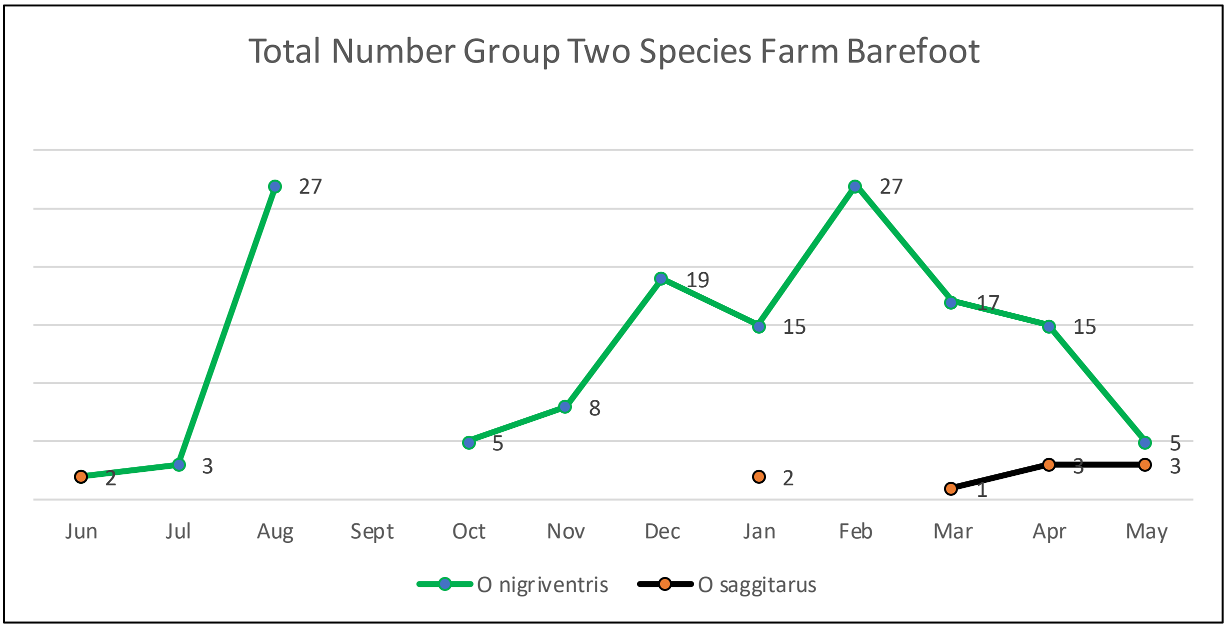


Figure 31: DBID-E total number of Group Two dung beetle species collected Farm Barefoot June 2021 – May 2022

Figure 32 displays the peaks in abundance of Group Three species of dung beetles across the 12 month collection period at Farm Barefoot. Numbers of O vanderkelleni were high at this farm and this species was found in every collection. There were no O viridulus identifed at this farm.

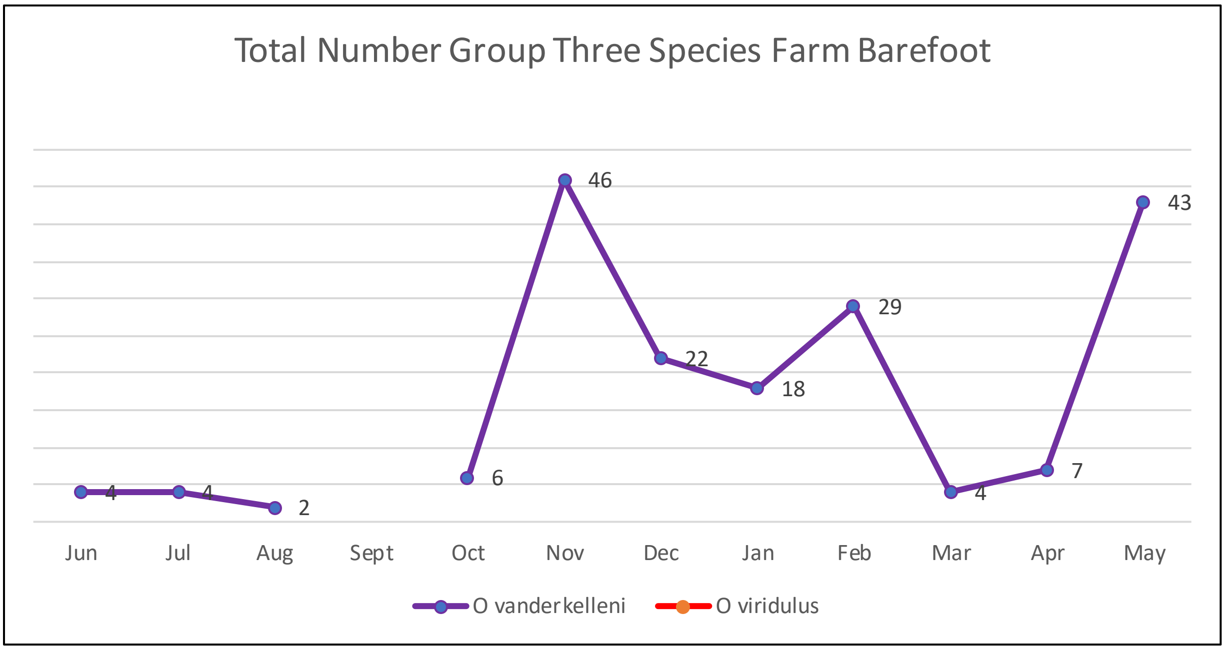


Figure 32: DBID-E total number of Group Three dung beetle species collected Farm Barefoot June 2021 – May 2022

Figure 33 displays the peaks in abundance of Group Four and Five species of dung beetles across the 12 month collection period at Farm Barefoot. Numbers of *S bicolour* peaked in April, and there were no collections of *A fimetarius* at this farm.

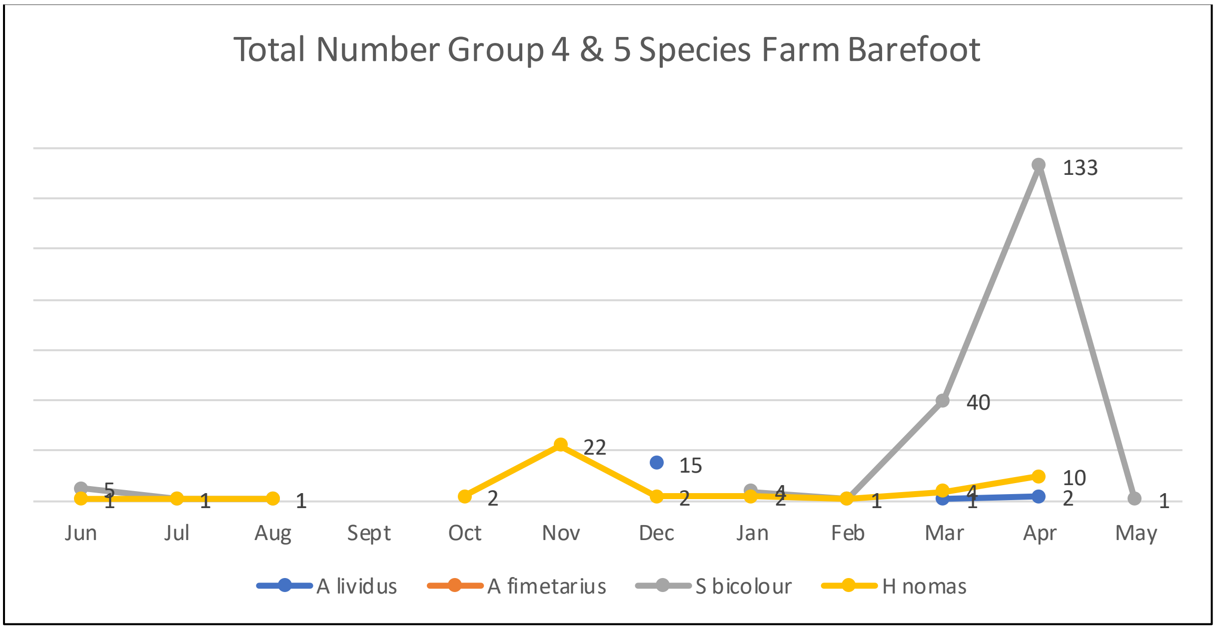


Figure 33: DBID-E total number of Group 4 & 5 dung beetle species collected Farm Barefoot June 2021 – May 2022

Farm Bundarra There were 10 separate species of beetle identified on this farm with most activity seen in February and March (Table 15). Numbers of *O vanderkelleni* were large compared to other farms and this species was collected in most months of the year. Peak beetle activity was in February and April.

Table 16: DBID-E Project: Farm Bundarra monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
E intermedius							2	2			1	
L militaris	1	1	1			1			1		3	
D gazella					28	2	6	6	57	14	2	4
O nigriventris			4	7	1		27	27	8		17	
O saggitarus	2			2			3	3	22	1	2	1
O vanderkelleni	1			6	1	23	8	8	37	1	34	14
A lividus	1								1	1		
A fimetarius									1			
S bicolour	6	11	5	22	9		12	12	43		58	4
H nomas	8	7	10	14	15	9			17	4	11	
TOTAL	**19**	**19**	**20**	**51**	**54**	**35**	**58**	**58**	**187**	**21**	**128**	**23**

Figure 34 displays the peaks in abundance of Group One species of dung beetles across the 12 month collection period at Farm Bundarra. Numbers of *D gazella* peaked in February. Overall, the numbers of this group were low at this farm.

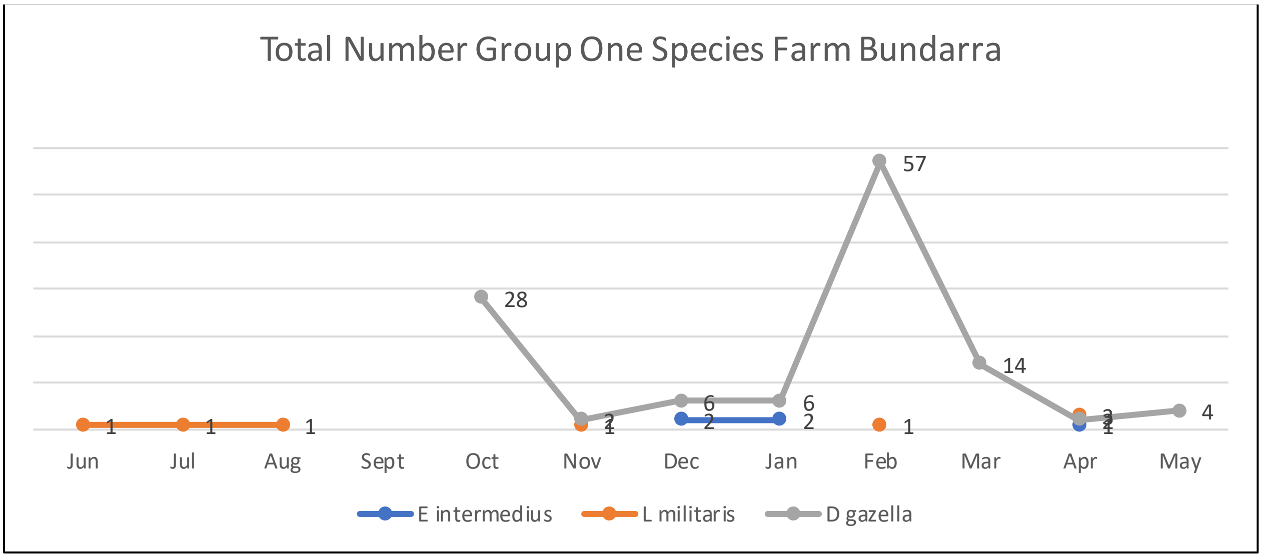


Figure 34: DBID-E total number of Group One dung beetle species collected Farm Bundarra June 2021 – May 2022

Figure 35 displays the peaks in abundance of Group Two species of dung beetles across the 12 month collection period at Farm Bundarra. The activity of *O nigriventris* was greatest in December and January, with another smaller peak in April, and in February for *O saggitarus*.

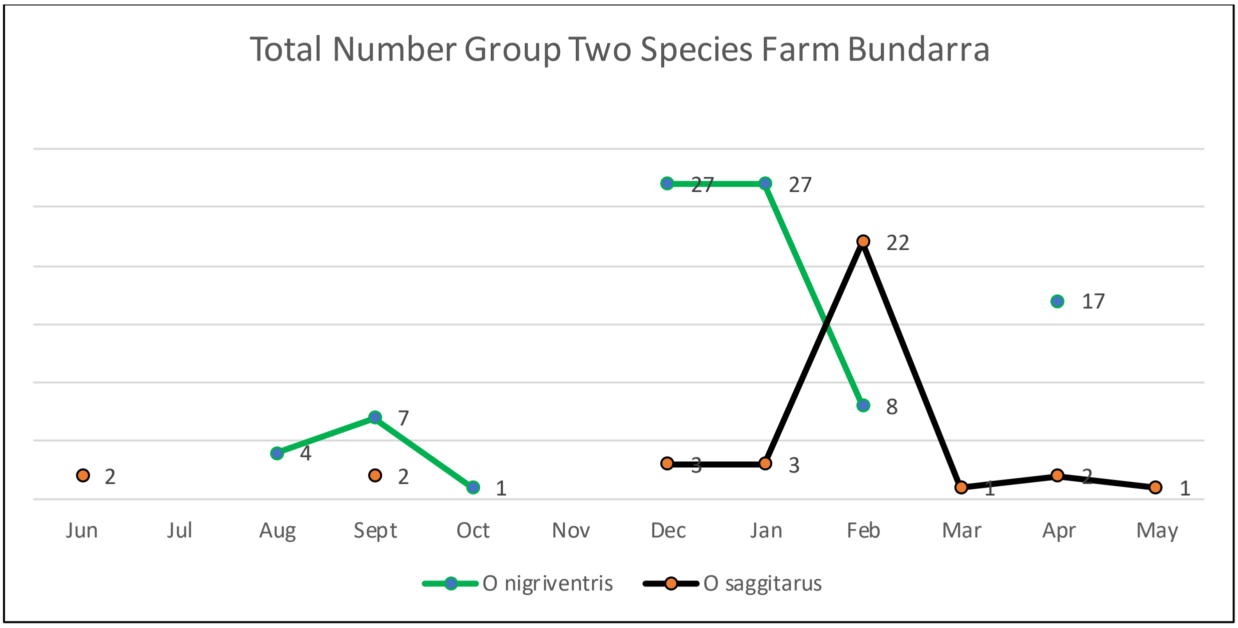


Figure 35: DBID-E total number of Group Two dung beetle species collected Farm Bundarra June 2021 – May 2022

Figure 36 displays the peaks in abundance of Group Three species of dung beetles across the 12 month collection period at Farm Bundarra. *O vanderkelleni* was collected in relatively large nubers compared to most other farms throughout the year. There were specimens of *O viridulus* collected at this farm.

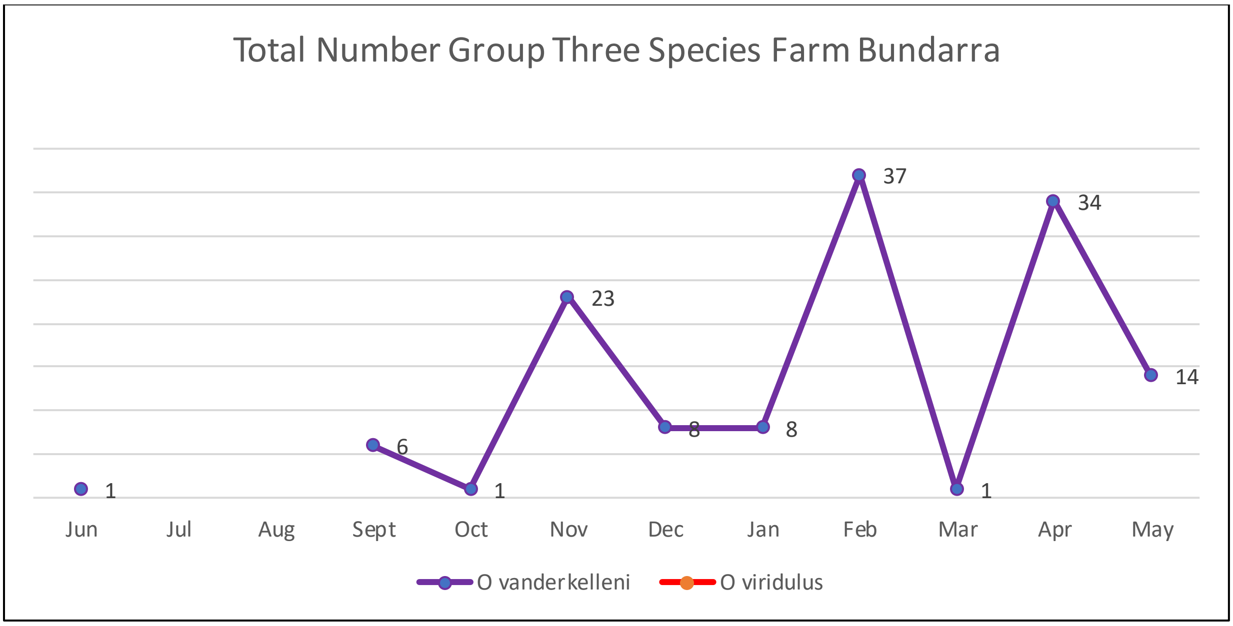


Figure 36: DBID-E total number of Group Three dung beetle species collected Farm Bundarra June 2021 – May 2022

Figure 37 displays the peaks in abundance of Group Four and Five species of dung beetles across the 12 month collection period at Farm Bundarra. Numbers of *S bicolour* and *H nomas* were relatively high compared to other farms and the beetles were active throughout most months of the year at this farm.

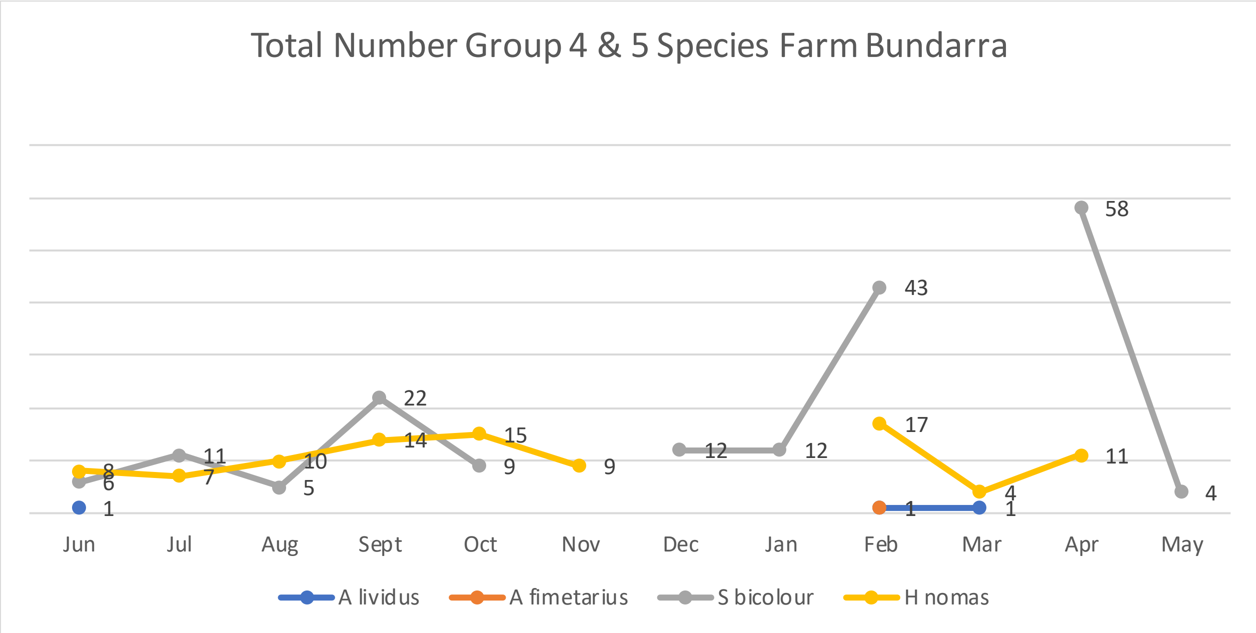


Figure 37: DBID-E total number of Group 4 & 5 dung beetle species collected Farm Bundarra June 2021 – May 2022

Farm BeatriceHills There were eight separate species of beetle identified on this farm with most activity seen from October to January (Table 17). Numbers of O nigriventris were relatively large compared to most other farms.

Table 17: DBID-E Project: Farm BeatriceHills monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
E intermedius						1	2					
D gazella					1	3	3	1	3			4
O nigriventris	9				17	3	20	72	1			
O vanderkelleni	1		1		1	1		7	3			
A lividus							35	2				
A fimetarius								1				6
S bicolour							2	5				
H nomas					2		6	7	3			
TOTAL	**10**		**1**		**21**	**8**	**68**	**95**	**10**			**10**

Farm Jaggan There were seven separate species of beetle identified on this farm (Table 18) and overall numbers were relatively high compared to some other farms. This property changed owners and was destocked for some months after the January collection.

Table 18: DBID-E Project: Farm Jaggan monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
L militaris						1		2				
D gazella					17	4	12	3				
O nigriventris	1	4		13	6	2	8	1				
O saggitarus			3	5	7	1	2	3				
O vanderkelleni	1		4		1	2	2	6				
S bicolour	5	13	3	7	3	3	20	3				
H nomas	4	8	3	4	14	7	2	7				
TOTAL	**11**	**25**	**13**	**29**	**48**	**20**	**46**	**25**				

Farm Quinola There were nine separate species of beetle identified on this farm (Table 19) and overall numbers were relatively high compared to some other farms.

Table 19: DBID-E Project: Farm Quinola monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
L militaris	24							7	1			
D gazella	1						14	7	19			
O nigriventris	4	1			3		2	12	4			
O saggitarus				1				1	1			
O vanderkelleni					2			3	2			
A lividus	1								8			
A fimetarius		1										
S bicolour	5				2							
H nomas	2			1	16			2	7			
TOTAL	**37**	**2**		**2**	**23**		**16**	**32**	**45**			

Farm Topaz There were six separate species of beetle identified on this farm (Table 20) and numbers were relatively good compared to other farms. However, there were no beetles found during the October collection.

Table 20: DBID-E Project: Farm Topaz monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
D gazella	10		2			2		9				
O nigriventris	10	1	10					1				
O saggitarus			36					4				
O vanderkelleni		2	3									
S bicolour	3	8	3			23						
H nomas	3	1	8			1		4				
TOTAL	**26**	**12**	**32**		**0**	**26**						

Farm Bro-Ton There were only four collections made from this farm during the year and there were five separate species of beetle identified (Table 21).

Table 21: DBID-E Project: Farm Bro-Ton monthly identification and abundance June 2021 – May 2022

	joined in July	July	August	Sept	October	Nov	Dec	Jan	Feb	Mar	Apr
E intermedius					4						
D gazella					1						
O saggitarus				2							
O vanderkelleni		3	1	1	5						
H nomas		2		2	1						
TOTAL		**5**	**1**	**5**	**11**						

Farm WinWe There were only two collections made from this farm during the year and there were six separate species of beetle identified (Table 22).

Table 22: DBID-E Project: Farm WinWe monthly identification and abundance June 2021 – May 2022

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
L militaris	10		1									
O nigriventris	6											
O saggitarus	2											
O vanderkelleni	8		1									
A lividus	2											
S bicolour	3		1									
TOTAL	**31**		**3**									

Native Beetles

Beetles found in dung assumed to be native beetles were sent to Dr Geoff Monteith (Queensland Museum) for formal identification (Box 1). These beetles were present on farmland adjacent to native eucalypt forest and very scarce or absent from farms which were located in regions of grassland derived from clearing rain forest. Numbers of these beetles were extremely low (less than 5 at any one collection) and spread across the year. The majority of all these beetles were collected at Farm Wondecla and Farm Cadaghi (neighbouring properties).

GEOTRUPIDAE

Elephastomus gellatus Carne 1965. Not a true dung beetle. A native species which occurs in eastern Australia from NE NSW to the NE QLD.

SCARABAEIDAE: SCARABAEINAE (true dung beetles)

Coptodactyla monstrosa Felsche 1909. A native dung beetle which occurs from Townsville north in Queensland. An open forest species.

Onthophagus capella Kirby 1818. A large black native, nocturnal, open forest species which occurs from southern NSW to the Atherton region.

Onthophagus conspicuus Macleay 1864. An all-green metallic native open forest dung beetle which occurs from about Bowen north to Cape York.

Onthophagus cuniculus Macleay 1864. A small metallic, bronzy day-flying, open forest native species which occurs in NE Queensland.

Onthophagus incornutus Macleay 1871. A small, dark, nocturnal native species which occurs along the east coast of Australia and reaches its northern limit in the Atherton region.

Onthophagus muticus Macleay 1864. A native, open forest species which occurs across the top of WA and NT and down through eastern Queensland to NE NSW. This is a prehensile species which has specialised claws enabling it to cling to fur of macropods until they deposit dung.

Onthophagus thoreyi Harold, 1868. A native, open forest species which occurs from southern Queensland north to the Atherton region.

Onthophagus tricavicollis Lea 1923. A black and metallic green, native, open forest species which occurs in NE Queensland.

:Information provided by Dr Monteith

Box 1: Native beetle identification

Farm Management Practices including chemical usage

Usual stocking rates and farm practices were maintained by most the farmers throughout the DBID Project. However, one farm changed owners and destocked and one farm destocked and then ran agistee cattle. Farmers were asked to report any chemicals or biodynamic/organic treatments used on the cattle, or in the pastures, during the project. 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 some 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 Weather

The DBID-E Project was conducted over a 12-month period (June 2021 – May 2022) thus included 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 sites. 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.

Generally speaking, the rainfall for the region during the DBID-E Project was about the recorded average, however, the summer storms were earlier than the previous year across most of the Tablelands. Some of the farmers keep daily rainfall logs and provided supplemental information to the DBID-E. Farm PCG has a higher average rainfall compared to Farm Wondecla and Figure 38 shows the monthly rainfall from both farms to highlight the differences in rainfall patterns across the Tablelands.

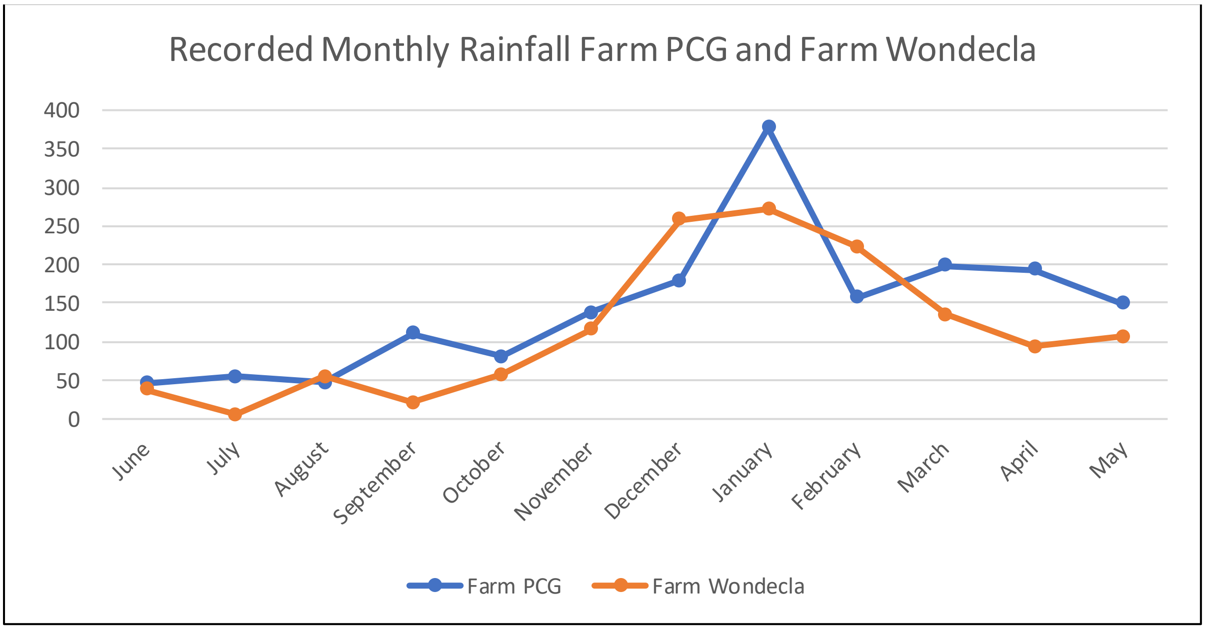


Figure 38: Recorded monthly rainfall Farm PCG and Farm Wondecla DBID-E

The early storms were reflected in the results as the beetles were active a month earlier than were recorded in the DBID Project. Farm Wondecla and Farm Cadaghi are neighbouring properties and we can assume the rainfall is the same for both properties. Figure 39 shows the increase in dung beetle activity (dung beetle Groups 1-4 totals in this figure) with the onset of the summer rains.

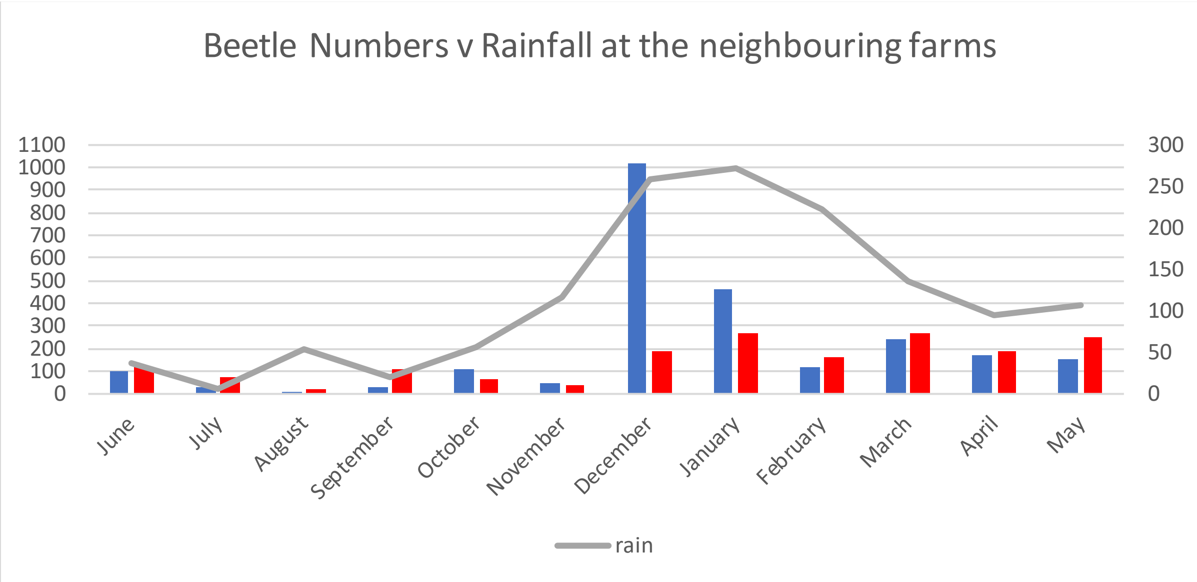


Figure 39: Total dung beetle numbers (Groups 1-4) compared to rainfall at the Wondecla farms DBID-E

Figure 40 shows the dung beetle activity (dung beetle Groups 1-4 totals in this figure) at Farm PCG and the monthly rainfall. Beetle numbers were considerably lower at this farm compared to Farm Wondecla and Farm Cadaghi however the total rainfall for the same timeframe was much higher (Farm PCG total = 1731mm compared to 1382mm for Farm Wondecla).

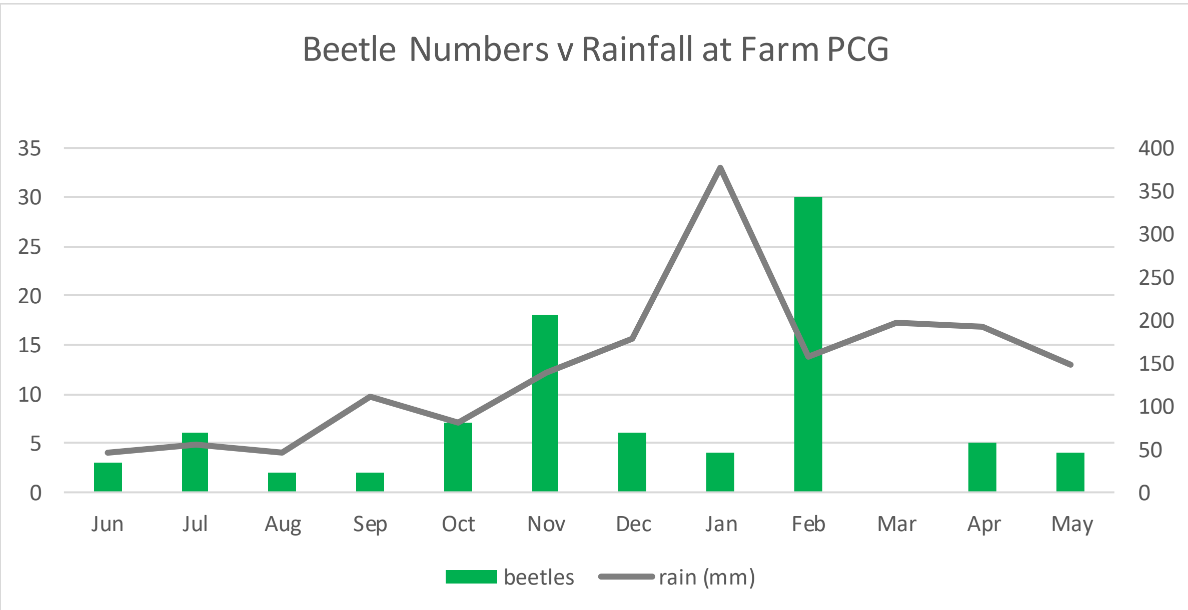


Figure 40: Total dung beetle numbers (Groups 1-4) compared to rainfall at Farm PCG DBID-E

Farmer Participation, Knowledge and Awareness

There were 15 Atherton Tableland farmers (and, by default, their families) who volunteered to participate in the project. 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 good and most farms collected and posted dung beetles every month. However, there were farms that dropped out and some collections were lost by Australia Post in transit for identification. Farmers were also asked to complete a number of surveys throughout the course of the project and not all completed the surveys. However, most farmers who participated in the project have verbally conveyed to LG or GA that they had learned a lot about dung beetles during the course of the project.

An information day was held on 12 February 2022 in Malanda and Dr Doube presented dung beetle and project information via videoconference. Due to COVID-19 concerns at that time, he was unable to attend in person. 32 attended in person with 6 attending online. Attendees included NRM and DAF staff who were able to make connections with local farmers interested in increasing dung beetle numbers. Discussions were conducted aboutwhich wormers and tick treatments are safer to use on cattle, horses and even dogs in order to preserve beetle health. The local vet was part of the farmer group undertaking the study and as such a more in-depth discussion was able to be held around the rates and when was necessary to treat stock for maximum benefit to the beetles and the stock. Organic and biodynamic farmers were also able to share experiences with the way they treat stock for flies and ticks.

Following the relaxation of COVID-19 restrictions, Dr Doube and Mrs Doube travelled to the Tablelands and met with a number of the project farmers. On site farm visits where Bernard Doube visited in with farmers at their properties occurred in the week of 18 July 2022. 7 farms were visited with a total of 13 farmers present to learn from Dr Doube. Dr Doube answered questions, discussed management options to improve the chances of beetles surviving and dug up beetles to look at which beetles were breeding at that time. Farmers also learnt about mites (that were present) that work with the dung beetles and are beneficial to the farm ecosystem. A final meeting was held after all of the field visits to discuss findings from the week and next steps for farmers. Media publicity about the project was published in the Tablelands Express newspaper and on the ABC radio and associated webpage in February, March, June and August 2022.Facebook posts have been on ABC, Terrain NRM, Cape York NRM. The project team would like to thank the ABC, Terrain NRM, Cape York NRM, Gulf Savannah and DAF staff as well as the Malanda Beef Plan Group who have supported the project through information sharing and promotion of the project activities.

Discussion

The DBID-E Project is a continuation, and extension, of a significant survey of the distribution and abundance of dung beetle species in Northern Queensland since 2002. The information obtained from the DBID and DBID-E Projects builds on, and contributes to, the body of dung beetle species survey work nationally and within Queensland. The information obtained from these projects 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 12 different introduced species of dung beetles at least once in the 12 months of collection and some of 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.

Six 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, O alexis*) 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 most farms (*A lividus* and *S bicolour*) were not part of the original CSIRO releases.

We discuss in detail each of the introduced dung beetle species found on the majority of farms in the DBID-E Project, and use data from the Qld Dung Beetle Project 2001-2002 and estimates from Doube[15] (2014) in this discussion of the DBID-E Project findings. Overall, the activity/seasonality of each species generally 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. When viewing the numerical data, it must be considered that not all farms recorded identifications for every month of the year. For the purposes of the tables and graphs to follow – the farms with the most complete datasets are only included (Wondecla, PCG, Platypus Creek, PCG, Biodynamic, Cadaghi, Bundarra, CedarValley, Barefoot).

[15] Doube & Marshall: Dung Down Under: dung beetles for Australia published 2014

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.

This species of dung beetle was identified at least once on every farm during the DBID-E Project collections (Figure 41). Farm Barefoot and Farm Bundarra had significantly more individuals of this beetle compared to the other farms. Farm Barefoot collected this species at 11 timepoints during the 12 months and had over 40 individuals of this beetle at two time points. Farm Wondecla also collected this species at 11 timepoints during the 12 months but in smaller numbers. Farm Bundarra and Farm Platypus Creek collected this species at 10 time points during the 12 months (Table 23). Numbers of this species at Farm Platypus Creek were significantly more than collected during the previous Project.

Table 23: O vanderkelleni total numbers by Farm DBID-E

	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
CedarValley	10	10	4	1	2	11		23					**61**
Bundarra	1			6	1	23	8	8	37	1	34	14	**133**
Biodynamic	6			4		6	1	3			4		**24**
PCG	3	6			1	8	1				1		**20**
Platypus Cr		2	4	9	5	1	19	4	5	4	6		**59**
Wondecla	5		1	10	6	6	2	6	yes	1	2	5	**44**
Cadaghi				1	12		8		yes	2	10	7	**40**
Barefoot	4	4	2		6	46	22	18	29	4	7	43	**185**
TOTAL	**29**	**22**	**11**	**31**	**33**	**101**	**61**	**62**	**71***	**12**	**64**	**69**	

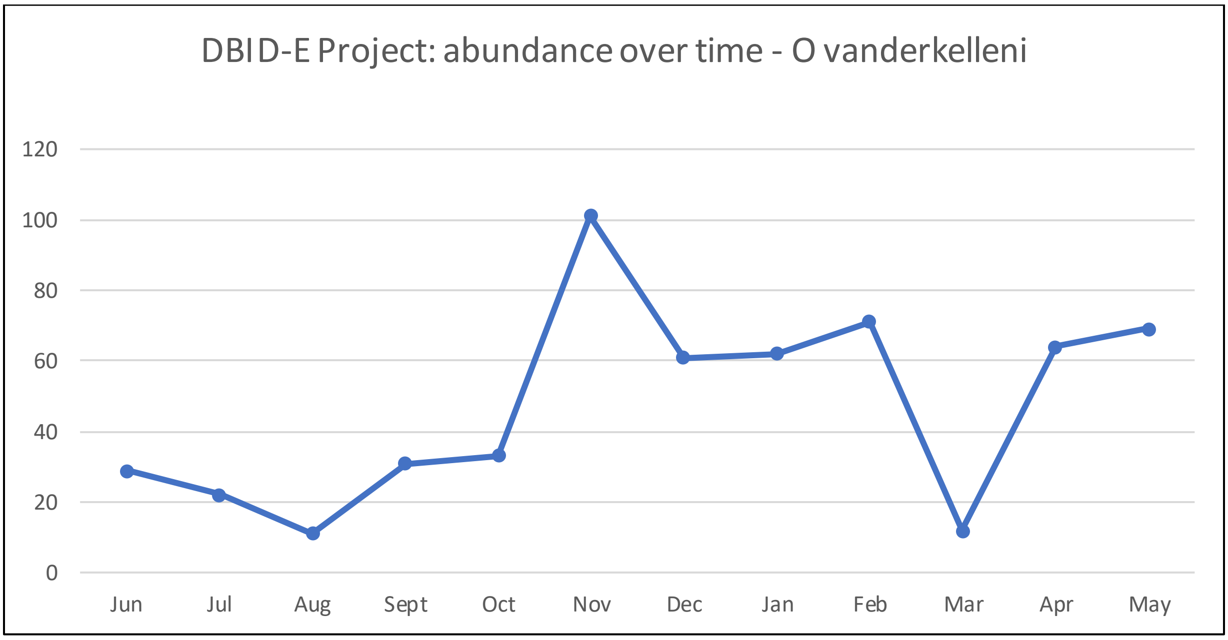


Figure 41: O vanderkelleni abundance over the DBID-E Project 12 months collection time period

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[16]. 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 some 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 generally low (less than 10 beetles per four dung pads) (Figure 42), and might be attributed to the volume of rain received in the region. Most of the 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 and Farm Cadaghi) had significantly more *D gazella* collections over the year. The results found from the Farm Wondecla/Farm Cadaghi sites 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/Ravenshoe). Due to reporting issues, the count for February is incomplete but at a minimum would be 90 individual beetles of this species.

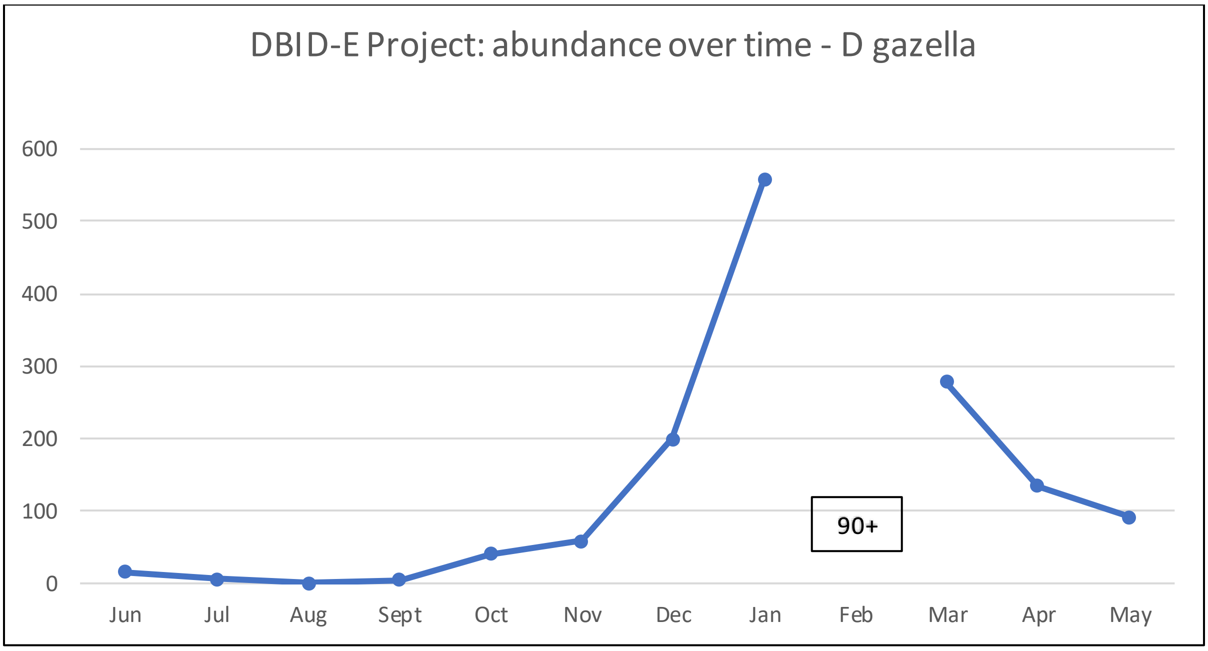


Figure 42: D gazella abundance over the DBID-E Project 12 months collection time period

[16] 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 a number of farms, the numbers were generally low (less than 10 beetles per four dung pads), and occurrence was intermittent, peaking at the rainy season. 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. While this species was not trapped at the Ravenshoe or Malanda site during the Qld Dung Beetle Project 2001-2002, specimens were identified at DBID-E Farm Barefoot in Ravenshoe.

However, samples were received from Tolga, Mt Molloy, Kairi and Yungaburra after the Qld Dung Beetle Project 2001-2002 training days. These locations could geographically link the original CSIRO release sites with the DBID-E Project farms explaining the distribution across the Atherton Tablelands, and also suggest further distribution north (Mt Molloy) and east (Kairi). The peak found in May during the DBID-E Project was the same month to the DBID Project results (Figure 43). Due to reporting issues, the count for February is incomplete but at a minimum would be 43 individual beetles of this species.

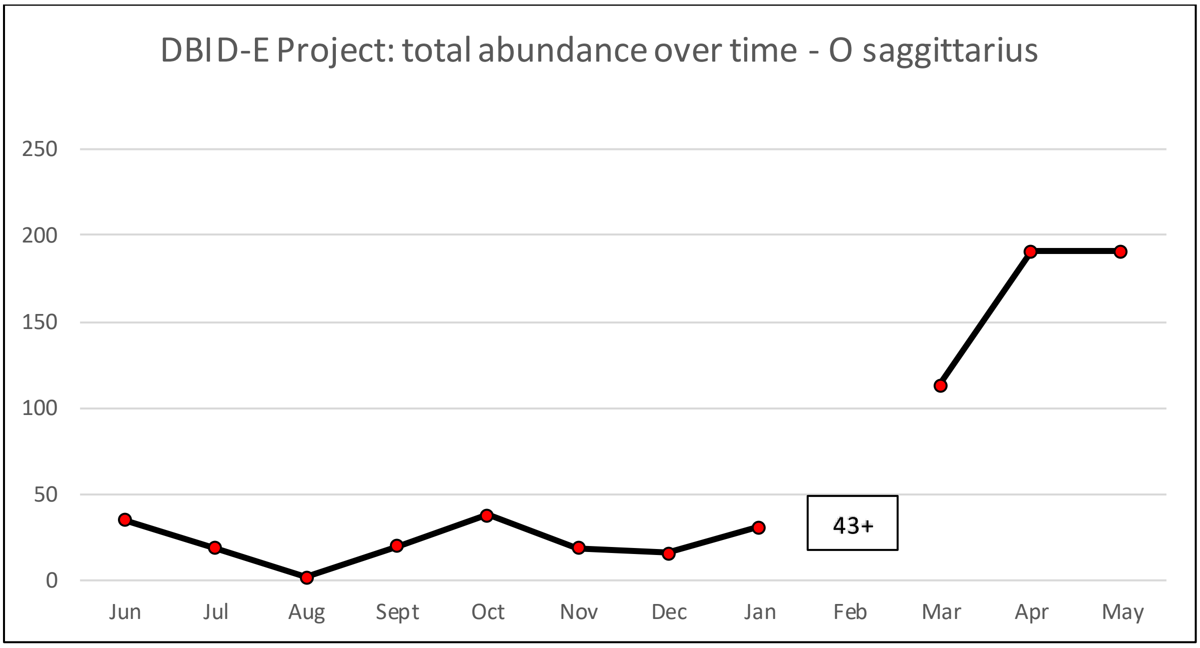


Figure 43: O sagittarius total abundance over the DBID-E Project 12 months collection time period

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 at two farms (Farm Wondecla and Farm Cadaghi) in December (over 800 individuals at Farm Cadaghi) and May, and in very low numbers in the dry season (Figure 44). Due to reporting issues, the count for February is incomplete but at a minimum would be 6 individual beetles of this species.

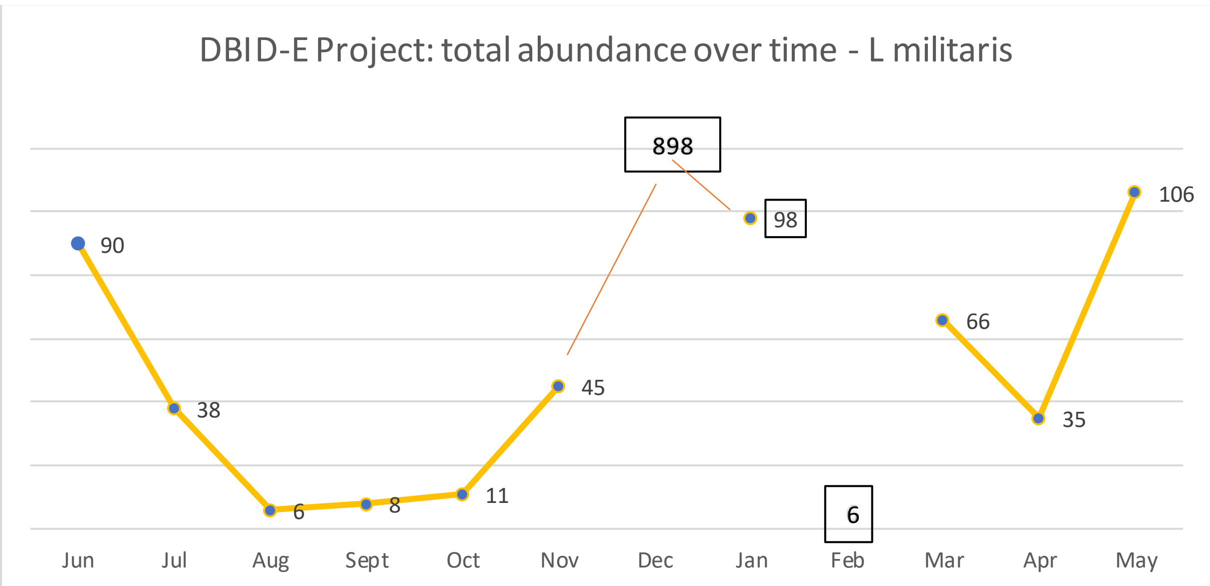


Figure 44: L militaris total abundance over the DBID-E Project 12 months collection time period

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 farms 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 (Figure 45), but not at all farms.

Farm Wondecla and Farm Cadaghi were the exceptions, consistently having higher numbers of specimens compared to most other farms. Farm Wondecla 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 both the DBID and DBID-E Projects, so may not have any of this species prior to the 2016 introduction. 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 DBID Project, however, this species was identified during the DBID-E Project. Due to reporting issues, the count for February is incomplete but at a minimum would be 2 individual beetles of this species.

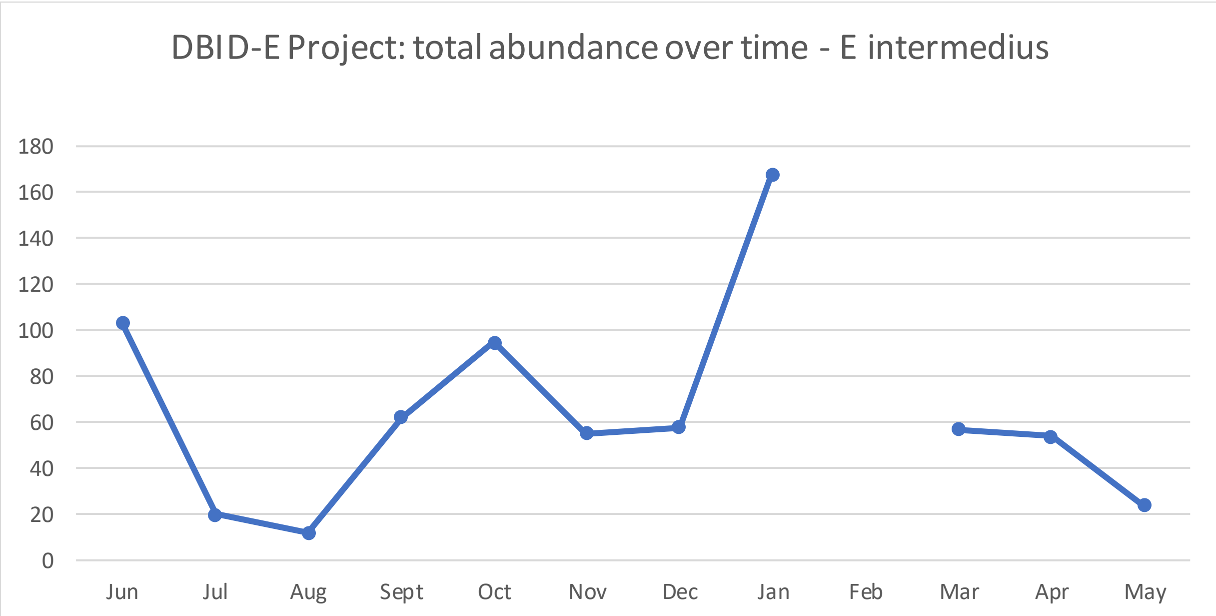


Figure 45: E intermedius total abundance over the DBID-E Project 12 months collection time period

Image: Atherton Tablelands. Photo Credit Tania Torrisi

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-E Project were made at Farm Barefoot, Farm Wondecla and Farm Cadaghi. Peak catches were made in January (Figure 46) which is different to that found in the DBID Project (October) and the August and February peaks found in the Qld Dung Beetle Project.

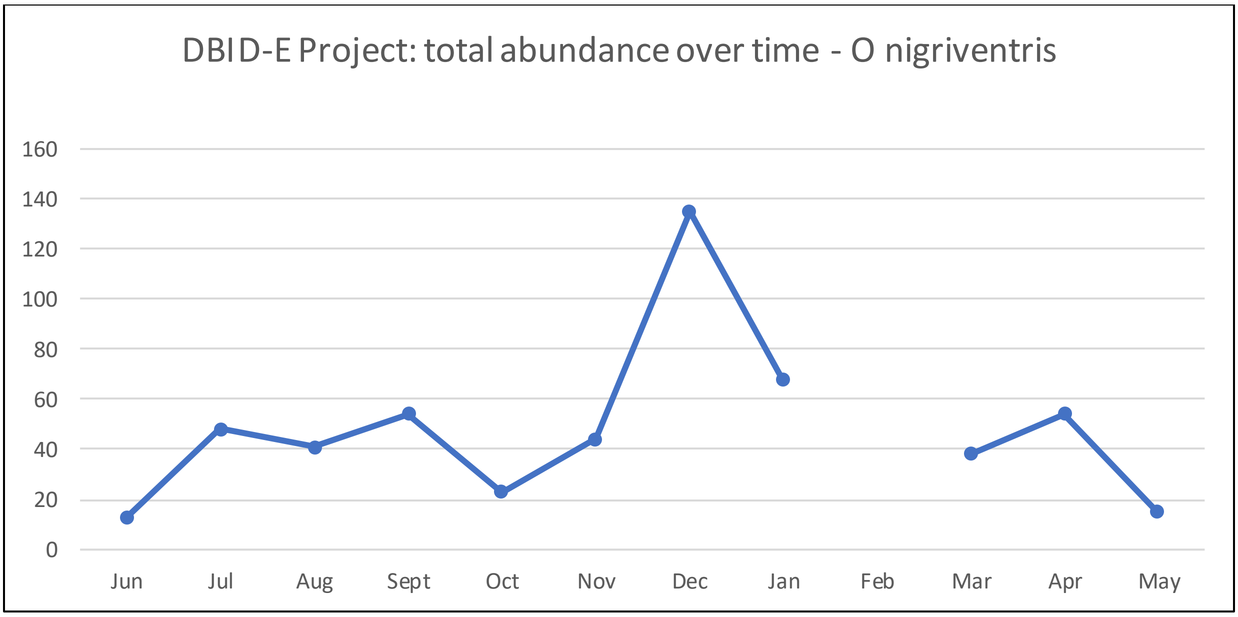


Figure 36: O nigriventris total abundance over the DBID-E Project 12 months collection time period

What did we find that we didn't expect?

O vanderkelleni was identified at least once on every farm during the DBID-E Project collections with Farm Barefoot and Farm Bundarra having significantly more individuals of this beetle compared to the other farms.

Farm Platypus Creek is separated by one property to Farm PCG, along the same road and on the same side of the road and they have similar farm management strategies (rotational grazing, beetle friendly chemicals). During the DBID Project, 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. However, in the DBID-E Project, total numbers and species at this farm were obviously greater than the previous year whilst Farm PCG were similar. In January 2021, approximately 300 dung beetles (a mixture of species) were transferred from Farm Wondecla to Farm Platypus Creek as a beetle exchange trial (in this instance – a one way transfer). Whether this transfer of beetles had influenced the number and diversity of species is outside the scope of this project to determine.

Farm Wondecla and Farm Cadaghi are neighbours and have different farm management practices: Farm Wondecla uses (sparingly and beetle friendly) chemicals on the cattle for worms, ticks and fly management whereas Farm Cadaghi does not. The collections for each month were done on the same day by the same person but there were slight differences in the both the abundance (Table 24) and variety of species between the farms (Table 25). The large collection of over 800 *L militaris* beetles at Farm Cadaghi in December was the largest single collection during the two years of the projects.

Table 24: Farm Cadaghi and Farm Wondecla total number of Group 1-4 beetles DBID-E Project

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Cadaghi	101	26	5	29	111	48	1019	463		244	169	150
Wondecla	116	72	23	112	66	43	191	271		264	188	250

Table 25: Farm Cadaghi and Farm Wondecla number of different species of the Group 1-4 beetles DBID-E Project

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Cadaghi	5	5	3	5	7	6	6	5		6	5	7
Wondecla	6	5	6	4	5	7	6	6		7	6	6

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 on most farms**. Some of the farms have been practicing dung beetle farm management strategies for over six 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-E Project reported seeing these animals active on their farms during the year.

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 hope 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 in great numbers, or at all, 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 we **have only found a single individual of this species in two years** (Farm Wondecla). 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 two years. These are all southern species, and it might not be expected for them to survive in this environment and climate[17].

[17] Personal correspondence Dr Bernard Doube

We found **no ball rolling dung beetles** in two years 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.

Dung Beetle Diversity and Abundance and Climate and Soil Type

The climate, soil type and soil moisture have important roles in how dung beetles can, or cannot, establish and thrive on farm. Different species of dung beetle require different soil types and tolerate different amounts of rainfall, and we found a definite change in beetle activity with the onset of the summer rains across all farms. All the farmers reported increased beetle activity at this time and this is reflected in the abundance of beetles collected across all sites at this time. However, activity of one species at one farm might be at a different time from another farm, despite being located nearby which may be related to soil type, temperature or soil moisture.

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-E 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, Farm Cadaghi, Farm Biodynamic (who both used no chemicals) and Farm Wondecla (who did use chemical products) had greater diversity of species compared to most other farms. There were chemicals commonly used across the farms to manage flies, ticks and worms and most of these were thought of as '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-E 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. 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-E Project

Farmers talking to farmers is powerful engagement tool for innovative projects. The farmers engaged with the DBID-E Project have become advocates for the dung beetle. The farmers share their knowledge with their families, neighbours and peers.

This network will continue to share information beyond the life of the project. This project has led to people being connected who are interested in soil health and dung beetles with other like-minded farmers. Connecting 3 dung beetle experts with local farmers; existing peer networks, a producer group (Malanda Beef Plan Group), local DAF and NRM staff and neighbours through emails, phone calls, farm visits, media promotions and a workshop. Farmers are contacting each other about best practice and lower chemical use on farms, they are asking each other how they can improve their practices to increase dung beetle populations and willingly sharing this within their group and to their peers beyond the group.

Limitations

This project was driven and conducted by a core group of five farmers and one Natural Resource Management representative. None of the group were entomologists or had any previous experience in scientific research about dung beetles, apart from the previous local DBID Project. Throughout the data collection stage of the project, Dr Bernard Doube contributed expert advice and guidance.

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[18].

Some 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.

Despite being asked to contribute considerable time and commitment to collect specimens monthly for one year, most of the farmers were diligent and committed to the project. However, there were farmers who dropped out of the project or failed to collect beetles every month. There were instances of specimens being lost in delivery by Australia Post en route to Dr Doube for identification 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[19]. Unfortunately, the identification records from two collections (Farm Cadaghi and Wondecla) were lost prior to entry into the database.

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 December to February.

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.

Five of the DBID and DBID-E Farmers and Louise Gavin (Remarkable NRM)

[18] 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).
[19] 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-E 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 are more likely to be available 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 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-E 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 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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We especially thank the dung beetles for their exemplary work in the field.

Postscript: How best to describe a dung beetle community?

Summary

One of the common questions asked about regional dung beetle populations is 'which species are present and how abundant are they?' Here I have addressed the problem of how to define and delineate local dung beetle communities and I consider the two Atherton Tableland surveys in relation to a 30-year data set (1972–2002) from Rockhampton Qld (900 km south).

From this analysis of the true dung beetles, it is clear that:

- There were huge year-to-year variations in total numbers (up to 26-fold between years)
- Three broad species groupings can be recognised in each location:
  - dominant species
  - subordinate species
  - rare species.
- Some species, depending upon the year, shifted between groupings.

Important differences between local regional communities even on the Atherton Tableland were detected. On cleared eucalypt woodland, with moderate rainfall, the community composition was similar to that at Rockhampton while the communities on cleared rainforest with higher rainfall were characterised by dominant species derived from high-rainfall regions overseas.

Long-term studies at Rockhampton have shown that each species has its own year-to-year changes in abundance and that species in the same community do not necessarily fluctuate synchronously, indicating that the factors that determine beetle abundance vary between species.

I also consider the hypothesis of functional equivalence, in which species with similar ecological attributes (e.g. the three *Onitis* species) can be viewed as one functional group; for example, when attempting to assess the amount of dung buried by a community of dung beetles.

Introduction

One of the common questions asked about regional dung beetle populations is 'which species are present and how abundant are they?' Together these species make up a regional dung beetle community but, as experienced field biologists have come to realise, such dung beetle communities are difficult to define, for several reasons:

- There are often dramatic year-to-year changes in total abundance, and in the relative abundances of individual species.
- There are obvious seasonal shifts in the activity of different species.
- The peak activity period of individual species can vary by several months, depending on climate (primarily rainfall and temperature).

Here I have addressed the problem of how to define and delineate local dung beetle communities and I consider the data from the two Atherton Tableland surveys in relation to a 30-year data set (1972–2002) from Rockhampton Qld (900 km south). Seven of the nine true dung beetles (scarabs) found in the Atherton Tableland surveys occur in both locations, and the two that occur in the Atherton Tableland data but are missing from Rockhampton (*Onthophagus nigriventris* and *Onitis vanderkelleni)* are true high-rainfall species.

Here I analyse the changes in community structure over a two-year period at six separate locations on the Atherton Tableland (i.e. in time and space) in relation to the 30-year data set from one location in Rockhampton (over time only).

Which species are present?

A list of species present in any region can be revealed by trapping and identifying beetles in different seasons of the year provided that the dung beetle community has had sufficient time to build up to substantial numbers and then to stabilise. This normally takes about a decade or more for multivoltine species (Figure 1). On the Atherton Tableland these species have proven to be highly dispersive and will have colonised the entire Tableland over the past decades. The dispersive capacity of *Digitonthophagus gazella*, for example, allowed it to fly and colonise Magnetic Island (4 km from the mainland) and Palm Island (20 km from the mainland) within a few years of it becoming abundant in the Townsville region. Since the new species on the Atherton Tableland were introduced over 30 years ago, we can assume that some form of equilibrium has been achieved. In my view, there is no benefit in introducing more colonies of such species, a view easily appreciated when we consider the current size of the dung beetle populations on the Atherton Tableland.

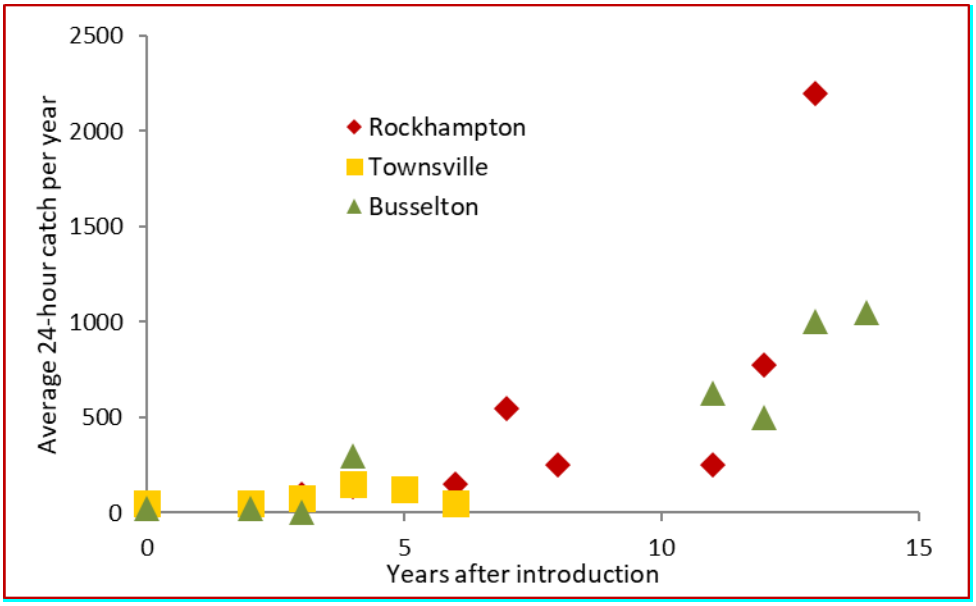

Figure 1 CSIRO introduced dung beetles to Australia in the 1960s. It took 4–6 years for moderate numbers to become obvious and a decade for beetles to become abundant. This was true in northern and southern Australia. Data here are for 24-hour traps per month averaged for 12 months. (adapted from Ridsdill-Smith & Edwards 2011 and Doube & Marshall 2014)[20]

Species composition within regions

The two recent Atherton Tableland dung beetle community studies provide a clear answer to the question 'Which species are present?'. We recognise seven distinct groups among the beetles trapped (Table 1). This list includes nine species of introduced true dung beetle (Scarabaeinae), seven of which are present 900 km south at Rockhampton (Table 2) and two other species which are

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[20] Ridsdill-Smith, TJ & Edwards, PB 2011, chapter 12 'Biological control: ecosystem functions provided by dung beetles', in LW Simmons & TJ Ridsdill-Smith (eds), *Ecology and evolution of dung beetles*, John Wiley & Sons, Chichester, UK.

Doube, BM & Marshall, T 2014, *Dung down under: dung beetles for Australia*, Dung Beetle Solutions Australia, Adelaide.

restricted to high-rainfall regions (*Onthophagus nigriventris*, *Onitis vanderkelleni).* There is also a group of native scarabaeine dung beetles, all of which are rare and largely restricted to properties on cleared eucalypt woodland (not cleared rainforest) and adjacent to eucalypt woodland inhabited by macropods and other native species. Present also are a number of species of *Aphodius* and the predatory species *Hister nomas* and *Sphaeridium bicolor.*

Table 1: Functional groups of species present in the Atherton Tableland dung beetle community

Group 1	Medium–small-sized species with a widespread subtropical geographical distribution	*D. gazella, E. intermedius, L. militaris*
Group 2	Medium-sized species with a highly restricted coastal high-rainfall distribution	*O. nigriventris*, *O. sagittarius*
Group 3	Large *Onitis* species	*O. viridulus, O. alexis*: a widespread subtropical geographical distribution O. *vanderkelleni*: a highly restricted coastal high-rainfall distribution
Group 4	Ball rollers	*Sisyphus spinipes*: recorded at Ravenshoe in the 2001–2002 Queensland Dung Beetle Project (QDBP) but was not recorded in either Atherton survey
Group 5	Native scarabaeine species	*Coptodactyla monstrosa* Felsche 1909 *Onthophagus capella* Kirby 1818 *Onthophagus conspicuus* Macleay 1864 *Onthophagus cuniculus* Macleay 1864 *Onthophagus incornutus* Macleay 1871 *Onthophagus muticus* Macleay 1864 *Onthophagus thoreyi* Harold, 1868 *Onthophagus tricavicollis* Lea 1923
Group 6	Very small *Aphodius* species	*A. lividus*, *A. (near) fimetarius*
Group 7	Predatory species that consume the eggs and larvae of dung-breeding flies	Include *H. nomas* and *S. bicolor*

Comparison between years, between locations and between species

Despite these promising generalities, closer examination leads to many puzzling differences in abundance.

At Rockhampton, seven of the Atherton Tableland species (*D. gazella, O. sagittarius*, *L. militaris, E. intermedius, S. spinipes, Onitis viridulus and O. alexis)* have been established for many decades. The 30-year Rockhampton data set (Table 2) allows comparisons of the year-to-year variations in the total number of beetles trapped (pooled across species) and species-specific comparisons between years. In contrast, the AthertonTablelands data provide the opportunity to compare the year 1 to year 2 variations in the total number of beetles trapped and species-specific comparisons between year and between locations.

The two sets of Atherton Tableland survey data have been summarised on a property-by-property basis (Table 3) and the data are presented as the average number of beetles of each species per sampling occasion over the entire year sampled (i.e. the total number of individuals trapped at each property divided by the number of sampling occasions in each year). This statistic is comparable to that presented for the Rockhampton data (average annual 24 hr catch for January to December given for years where trapping occurred in all 12 months (Ridsdill-Smith & Edwards 2011)) except that the Rockhampton data are based on dung-baited pitfall traps while the Tablelands data are based on direct extraction from field dung pads. The latter will provide a substantially lower number of individuals than that derived from pitfall traps.

Table 2 Average summer 24-hr trap catch (Dec to Mar) for eight species of introduced dung beetle from traps baited with fresh cattle dung at Rockhampton, Queensland, between 1971 and 2002. Average annual 24-hr catch for Jan to Dec given for years where trapping occurred in all 12 months (Ridsdill-Smith & Edwards 2011).[21]

	1972	**1973**	**1974**	**1975**	**1976**	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**	**1984**	**1985**	**1986**	**2002**
D. gazella	63	56	63	147	159	103	119	230	68	132	230	65	253	87	511	107
O. sagittarius	5	3	33	34	29	14	3	15	5	5	4	1	3	1	7	3
L. militaris			1	8	19	42	21	78	21	40	169	9	139	35	112	12
E. intermedius					32	37	51	324	66	180	192	59	1344	233	902	486
S. spinipes					11	36	35	483	48	34	70	1	1807	618	303	7
Onitis viridulus								<1		1	1		7	6	7	0
S. rubrus															8	73
Onitis alexis																<1
Average summer 24-hr trap catch (Dec–Mar)	67	58	97	189	251	231	229	1129	206	393	666	135	3552	979	1847	688
Average annual 24-hr trap catch (Jan–Dec)	47	36	85	130	123	114	541	247			230	807	2235			

Table 3: Mean per sampling occasion for each species for collaborators (Year 1: May 2020 to May 2021 inclusive and Year 2, June 2021 to May 2022 inclusive) Cadaghi Year 2 was physically adjacent to Wondecla

Species /	Wondecla		Cadaghi^	PlatypusCreek		Dairy*	FTW		Biodynamic		PCG		Totals	
Samling year	**1**	**2**	**2**	**1**	**2**	**1**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
D. gazella	20	49.6	51.3	0.4	4.5	0.6	4.3	1.3	3.4	7	1.6	2.2	5.1	18.2
O. sagittarius	3.6	32.8	19.5	0.5	1.4	0.3	0.9	0.9	0.5	1.1	1.5	2.2	1.2	9
L. militaris	22.5	16.8	102	0.1	0.1	0.3	2.7	1	0.5	5.3	14.7	0.2	7	18.7
E. intermedius	20.5	23.3	27.2	0.7	1	0.3	0.6	0	1.1	0.2	2.9	0.1	4.5	8.6
O. viridulus	0.7	0.2	0.5	0	0.2	0	0	0	0.3	0	0	0	0.2	0.1
O. alexis	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0
O nigriventris	11.3	9.9	11	0.2	1.3	0.5	2.8	0	2.1	3.2	1.5	1.1	3.5	5.9
O. vanderkelleni	1.3	3.7	3.6	0.5	4.9	0.4	0.4	0.1	0.9	2.2	2.7	1.7	1.3	4.8
Totals	**79.9**	**136.4**	**215.1**	**2.4**	**13.4**	**2.4**	**11.7**	**3.3**	**8.8**	**19**	**24.9**	**7.5**	**22.8**	**65.3**
A. lividus	26.4	5.8	6.4	5.2	4.8	6	95.5	6.6	3.8	5.1	15.5	25.1	26.7	7.9
A. nr fimetarius	0.2	1.7	3.2	0	2.4	0	0.7	0.3	0	0.5	0.2	7.6	0.2	2.3
H. nomas	1.3	1.9	2.6	1.9	4.8	1.9	1.3	0.7	1.8	3.4	3.9	3.1	2	3.1
S. bicolor	2.9	8.5	15	6	9.8	4.3	0.8	0	5.3	5.8	5.7	2.4	4	8.8
Totals	**30.8**	**17.9**	**27.2**	**13.1**	**21.8**	**12.2**	**98.3**	**7.6**	**10.9**	**14.8**	**25.3**	**38.2**	**32.9**	**22.1**

Total abundance (pooled across species) across years

- Overall, at Rockhampton, the total abundance of dung beetles varied substantially between years, the greatest observed difference being 1983 and 1984 when the mean totals were 135 and 3552 beetles per trap respectively (26-fold greater) (Table 2).
- Overall, on the Atherton Tablelands, the total abundance of dung beetles (pooled across scarabaeid species) varied about 3-fold between years, with the mean total in years 1 and 2 being 22.8 and 65.3 beetles per year, respectively (Table 3). For each species, the year 1 and year 2 pooled totals conformed largely to the same year-to-year pattern (year 2>year 1). However, that is where the similarities cease.
- Conclusion: the numbers of dung beetles present each year, and in both locations varies enormously, probably in response to rainfall.

Total abundance on the Tablelands (pooled across species) between locations and between years

- There were no consistent trends between locations in total numbers between years (Table 3). For example, at Farm Wondecla the year 1 and year 2 total were relatively similar (80 and 136 beetles respectively), whereas at Petersen's there were three times as many in year 1 as in year 2 (25 and 8 beetles respectively) and, in contrast, at Farm Platypus Creek the reverse was true, with almost six-times as many recovered in year 2 compared with year 1 (2 and 13 respectively). There is no obvious explanation for these differences.

Total abundance for each species between locations on the Tablelands within years

- The paired Atherton Tablelands sampling occasions offered the opportunity to compare species patterns over the two years. Overall, the abundance of individual dung beetle species varied substantially between years and locations. For example, for *D. gazella*, numbers in year 1 ranged from 0.4 to 20 beetles per location and 0 (zero) to 49.6 beetles per location in year 2 (Table 3). Similar massive within-year differences occurred with other species. For example, *L. militaris* numbers in year 1 ranged from 0.1 to 27 beetles per location and in year 2 they ranged from 0.1 to 16.8 beetles per location (Table 3). No clear patterns were detected.

Total abundance for each species between locations and years

On the Atherton Tableland

- Overall, there was a degree of consistency with scarce species remaining scarce and the dominant species remaining abundant but there was little consistency in relative abundance of the dominants between years and locations.
- Examples of the irregular patterns of species abundance are given above

At Rockhampton

- Overall (with the notable exception of *S. spinipes*), there was a degree of consistency, with scarce species remaining scarce and the dominant species remaining abundant but there was little consistency in relative abundance of the dominants between years
- *O. sagittarius* (established at the same time as *D. gazella*: 1972) increased to moderate numbers (annual average of 34 beetles per trap in 1975) then became relatively scarce following the establishment of a more complex dung beetle community. Its primary distribution has now contracted to higher rainfall coastal districts, which may help explain why it is relatively more successful (i.e. a more dominant species) in the high–rainfall Atherton Tablelands than at Rockhampton. Interspecific competition in a marginal environment is a likely explanation for its decline at Rockhampton.

- In contrast, *D. gazella* established and increased in numbers over a few years at Rockhampton and has remained one of the dominant species over the 30 years but its abundance varied nearly 10-fold between years (range 56–511 beetles per trap).
- Similarly, *E. intermedius*, once introduced to Rockhampton, quickly became a dominant species but its abundance varied nearly 23-fold between years (range 59–1344 beetles per trap).
- *L. militaris*, once introduced, quickly became a sub-dominant species but again its abundance varied nearly 19-fold between years (range 9–169 beetles per trap).
- *S. spinipes* (a ball roller), once introduced, became dominant in 1989 after only 4 years (483 beetles per trap) and 4 years later (1983) became very scarce (1 beetle per trap), but the following year it bounced back, achieving the astonishing number of 1803 beetles per trap. Its co-generic, *S. rubrus* remained relatively rare following establishment in 1986, increasing to between 8 and 73 beetles per trap in 2002.
- None of these species fluctuated synchronously with each other. One year favoured one species, another year, another species. For example, in 1984 *E. intermedius* and *S. spinipes* were both enormously abundant (1344 and 1807 beetles per trap), while *D. gazella* and *L. militaris* had only an average year. Many other instances of lack of synchrony are evident in the data in table 2.
- The two *Onitis* species were relatively rare throughout the sampling period.

Conclusion: For each species at both locations, there were massive year-to-year changes in abundance and in relative abundance, with different species prospering in some years, but not others, and none varying synchronously. On the Atherton Tablelands, there were also substantial year-to-year variations between regions.

Seasonal activity

The seasonal activity of the species present is also answered by the Atherton surveys. *O. nigriventris* is clearly a spring-active species with a possible autumn emergence as well, suggesting one, or perhaps two, generations per year, primarily focussed in spring and autumn but with some presence in summer. The spring activity of this species appears to begin later in the cooler regions than in the warmer regions. *O. vanderkelleni* appears to be present throughout the year but is more common in warmer seasons. The remaining moderately abundant species (*D. gazella, E. intermedius, L. militaris* and *O. sagittarius)* appear to be summer-active, as has also been observed at Rockhampton and in many other locations, while the two *Onitis* species (*O. alexis* and *O. viridulus*) are both scarce and summer-active on the Tablelands and at Rockhampton (Table 2). There were too few native beetles to clearly delineate their seasonal activity.

But this leaves unanswered the question of the relative abundance of these species over time.

Discussion

The substantial variations between years in the abundance of individual species, and in the total numbers of beetles within a local community (pooled across species), make abundantly clear that monitoring over a number of annual seasons is required in order to provide a comprehensive description of regional dung beetle communities and, further, the beetles' responses to climate and weather need to be understood. Similarly, the large variations between local communities in the same season indicate that a variety of geographic and management factors are influencing the composition of local dung beetle communities.

Despite these caveats, the local dung beetle communities can be described in broad terms as comprising a series of dominant, subordinate and relatively scarce species. Long-term studies at Rockhampton have shown that each species has its own year-to-year changes in abundance and that species in the same community do not necessarily fluctuate synchronously, indicating that the factors that determine beetle abundance vary between species, even over the long term. For example, in northern Australia, *D. gazella* and *E. intermedius* occupy similar distributions and yet their abundance did not fluctuate synchronously at either location. In 12 of the years between 1976 and 2002 at Rockhampton, *D. gazella* was the more abundant species in four summer seasons, in some summers the two species were equally abundant, and in others *E. intermedius* was the more abundant. Over the same period, a third species, the ball roller *S. spinipes*, showed yet another pattern of abundance. The same three species are present in complex South African dung beetle communities that may contain 100 or more species, but the year-to-year changes in their relative abundance in complex communities are at least as variable as observed in simple communities (a few species) in Australia.

Can one augment established dung beetle communities?

Let us consider the effects of introducing additional colonies of, say, the summer-active *D. gazella* and *E. intermedius* to the Tableland. How many are currently present during summer? With 90,000 cattle each producing 12 pads per day and each pad containing, say, 10 beetles and each beetle staying in association with each successive dung pad for say 10 days, a standing population of live beetles in dung pads at any one time during the beetles' activity season may be in the order of 11 million beetles per species (90,000 x 12 x 10 x 10). Clearly the addition of a small number of colonies (1000 beetles each) of these two species will have little or no influence on the overall populations on the Tableland and so, in my view, there is no point in introducing more of the relatively abundant species. But what about species which are present but in low numbers? Again I suggest that it is inadvisable to reintroduce such species because they have had decades to reach equilibrium numbers and distribution, as determined by environmental constraints and are unlikely to increase or spread further.

Instead, we should seriously consider introducing a suitable species that are not currently present.

Functional equivalents along ecological gradients

Attempts to quantify the economic benefits derived from dung beetle activity are made difficult by the diversity of species present and their idiosyncratic activity in relation to season, weather, climate and soil type.

In the scientific literature there is a theory, called the neutral model, that communities along an ecological gradient contain functionally equivalent species (i.e. having similar ecological attributes) and, while their distributions overlap, they progressively replace each other along the ecological gradient. As a consequence, from a functional perspective, these functionally equivalent species can be viewed as a single entity, thereby simplifying functional analysis; for example, when attempting to assess the amount of dung buried by dung beetles along an ecological gradient. For example, *Euoniticellus fulvus*, *E. pallipes, E intermedius* and *E. africanus* display similar functions in relation to breeding and methods of dung burial, and so it is likely that the individual species could be substituted by a '*Euoniticellus*' category into a model that would include the four species.

In these data we can observe a progressive dominance of different species as we move south from the Atherton Tableland, through Rockhampton in New South Wales. Considering dung burial by medium-large dung beetles as one ecosystem service, we have *O. nigriventris*, O. *vanderkelleni, O. sagittarius* as the dominant dung buryers on the high rainfall Tableland (cleared rainforest), *D. gazella, E intermedius,* and *L militaris*, (possibly *S. spinipes*) as the dominants buryers in wet tropical (cleared eucalypt woodland) and *O. alexis* and *O. viridulus* (and possibly *S. rubrus*) as the dominants buryers in NSW.

This view of dung beetle communities as functional entities that provide a range of ecosystem services enables analysis of beetle-promoted processes (such as dung burial or the promotion of pasture production) across regions that contain contrasting arrays of dung beetle at the species level.

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31 October 2022

APPENDIX ONE: DUNG BEETLE NURSERY

Farm Wondecla trialled a dung beetle raising nursery during the DBID-E project. The nursery consisted of two garden bed frames were enclosed by a fly mesh. At the onset of beetle activity in November, up to 40 dung beetles (of a variety of species) were taken directly from the paddock and placed into a fresh dung pad inside the nursery. Fresh dung was placed into the nursery at weekly intervals over the next 8 weeks, and then fortnightly for 8 weeks. A large storm in February damaged the original walk-in nursery structure and the nursery was downsized to a "teepee' version (see photo below).

Dung beetles were successfully raised during this trial (see photo), but in small numbers and mostly the larger O vanderkelleni.

APPENDIX TWO: BEETLE SWAPPING SUGGESTED BIOSECURITY PROTOCOL

Dung beetles can be harvested from areas when they are in their peak season. Several projects across Australia have trialled this procedure with the aim of increasing beetle numbers and distribution. In Tasmania, farmers were invited to board the "Beetle Bus". Equipped with buckets and trowels, they would travel to a farm during peak seasonal activity and harvest beetles from traps that had been previously set. The Dung Beetle Express Project in the Northern Tablelands NSW has also conducted extensive harvesting and release programs. In conjunction with the Queensland Dung Beetle Project this group developed guidelines on harvesting and releases for a range of species. The guidelines aimed to reduce the possibility of transferring weed seeds and soil-borne diseases from farm to farm.

Based on the interest from DBID Project farmers in potentially transfering dung beetles between farms, a biosecurity protocol was drafted by the DBID Project team. This protocol was based on existing documents found in the public domain and amended with thanks to those authors. The protocol was trialled successfully during the transfer of dung beetles from Farm Wondecla to Farm Platypus Creek. Beetles should be harvested at the beginning of their activity period to maximise the time available for egg-laying at the release site. Care should be taken when transporting beetles to ensure that environmental stresses are kept to a minimum and delivery to the new farm is as soon as possible following collection and washing of the collected beetles.

DBID-E PROJECT DUNG BEETLE TANSFER PROTOCOL

THERE IS A RISK OF TRANSMISSION OF SOIL BORNE DISEASES AND WEED SEEDS IN DUNG BEETLE TRANSFERS. IN ANY TRANSFER OF DUNG BEETLES, BOTH PARTIES NEED TO BE AWARE OF THIS RISK.

THE DBID-E PROJECT TAKES ALL CARE BUT NO RESPONSIBILITY WITH THE TRANSFER OF DUNG BEETLES BETWEEN PROPERTIES.

SUGGESTED METHOD FOR TRANSFER:

1. ALL BEETLES TO BE PLACED IN A PLASTIC TUB WITH COOL, NON-CHLORINATED WATER AND RINSED. REPEAT THIS RINSING WITH CLEAN WATER.
2. AFTER RINSING, PLACE THE BEETLES IN A CONTAINER WITH CLEAN DAMP PEAT MOSS (LID MUST HAVE SUITABLE SMALL HOLES FOR AERATION).
3. RECOMMENDED HOLDING TIME IS A MINIMUM OF 24 HOURS TO ALLOW INGESTED DUNG TO BE PURGED.
4. PRIOR TO DELIVERY, THE BEETLES SHOULD BE RINSED TO REMOVE PURGED MATERIAL AND THEN PLACED IN CLEAN FRESH DAMP PEAT MOSS FOR DELIVERY.
5. DELIVERY SHOULD BE AS SOON AS POSSIBLE AFTER STEP FOUR ABOVE.
6. ALL EQUIPMENT USED FOR RINSING SHOULD BE THOROUGHLY CLEANED AND THE PEAT MOSS BURNT TO AVOID CONTAMINATION.

TRANSFER DECLARATION

I.. OF ....
(OWNER OF FARM COLLECTING BEETLES) (LOCATION OF FARM COLLECTING BEETLES)

DECLARE THAT I HAVE NO KNOWLEDGE OF THE FOLLOWING DISEASES BEING PRESENT OF SUSPECTED OF BEING PRESENT ON THE ABOVE PROPERTY

- OVINE JOHNES DISEASE
- BOVING JOHNES DISEASE
- FOOT AND MOUTH DISEASE

SIGNED: ____________________________________ DATE:______________________________

I.. OF ....
(OWNER OF FARM RECEIVING BEETLES) (LOCATION OF FARM RECEIVING BEETLES)

DECLARE THAT I HAVE READ AND UNDERSTAND THE CONDITIONS ABOVE.

SIGNED: ____________________________________ DATE:______________________________

APPENDIX THREE: DUNG BEETLE IDENTIFICATION ATHERTON TABLELANDS (1960 – 2022)

CSIRO Release 11 species 1960-1980	Qld Beetle Project Identification 2002 Malanda Ravenshoe	MBPG Release 2016	DBID-E Identification 2020-2022
D gazella	D gazella	D gazella	D gazella
O nigriventris	O nigriventris		O nigriventris
O vanderkelleni	O vanderkelleni		O vanderkelleni
E intermedius	E intermedius	E intermedius	E intermedius
O viridulus			O viridulus
L militaris	L militaris		L militaris
O sagittarius			O sagittarius
H nomas			H nomas
E africanus		E africanus	
O alexis		O alexis	O alexis
O foliaceus			
	S spinipes	S spinipes	
		S rubrus	
		O binodis	

DBID-E Identification 2020-2022

A lividus
A fimetarius
S bicolour

DUNG BEETLE IDENTIFICATION

ATHERTON TABLELAND DBID-E PROJECT

Aphodius lividus

Sphaeridium bicolour

Hister nomas

Euoniticellus intermedius (male)

Euoniticellus intermedius (female)

Liatongus militaris

Onthophagus gazella (female)

Onthophagus sagittarius (male)

Onthophagus sagittarius (female)

Onthophagus nigriventris (male)

Onthophagus nigriventris (female)

Onitis vanderkelleni (male)

Onitis vanderkelleni (female)

Onitis viridulus (male)

Onitis viridulus (female)

Dung Beetles Identified by Dr. Bernard Doube: www.dungbeetlesolutions.com.au
Photography: www.postlephotography.com.au
Project Information: www.remarkablenrm.com.au
February 2022

Australian Government
National Landcare Programme
REMARKABLE NRM