the **Queensland Dung Beetle** *project*

Improving sustainable land management systems in Queensland using dung beetles

Final Report of the
2001-2002 Queensland Dung Beetle Project

Natural Heritage Trust
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IMPROVING SUSTAINABLE LAND MANAGEMENT SYSTEMS IN QUEENSLAND USING DUNG BEETLES

The information contained in this report is derived from samples collected during the 2001-02 NHT Queensland Dung Beetle Project. The report has been prepared for the landholders who assisted in the trapping of dung beetles throughout Queensland. It was prepared by Penny Edwards (Technical Co-ordinator) on behalf of the Management Committee of the Queensland Dung Beetle Project. Information contained herein may not be published without permission of AgForce Queensland or the author.

Acknowledgements

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1. INTRODUCTION

i) Background to project

The 2001-2002 Queensland Dung beetle project had its origins in the CSIRO Australian Dung Beetle Project that, in Queensland, ran from the late 1960s until 1986.

The rationale of the highly successful CSIRO project was to introduce exotic dung beetles into Australia in order to redress the production and environmental problems caused by large accumulations of unburied cattle dung. In particular, it was hoped the project would result in the biological control of the dung-breeding buffalo flies and bush flies, as well as providing major benefits to agriculture and the environment, through the recycling of nutrients, improved soil health and structure, better infiltration of water and reduced run-off. The project was initiated and developed by Dr George Bornemissza of CSIRO Entomology, and received considerable long-term financial support from the then Australian Meat Research Committee. Although dung beetles can effectively bury sheep dung, the support from the cattle industry resulted in an emphasis on selecting dung beetles suited for cattle dung.

A large staff of scientific and technical personnel, based at several locations in Australia, and in South Africa and Europe, contributed to the success of the CSIRO project. The main project was terminated in 1986 when industry funding was withdrawn. By 1986, 43 species of scarabaeid dung beetles had been released into Australia, 29 of these into Queensland. Smaller projects were funded in southern states for a few more years.

Following the closure of the CSIRO project, public interest in dung beetles declined in Queensland, and there was little follow-up work to determine the fate of many of the species that had been released in earlier years.

A revival of interest began in 1998, when Mick Alexander of the Taroom Shire Landcare Group invited John Feehan, the manager of Soilcam, to present two information seminars on dung beetles. This was followed by a two-week survey in January 1999, conducted by Soilcam, to record the establishment of introduced dung beetles in south-east Queensland. This survey was sponsored by Meat and Livestock Australia, Taroom Shire Landcare Group, Springwater Producer Group and Gympie Beef Liaison Group.

In December 1999 a group of graziers, scientists, and representatives from government agencies, industry and community groups met in Brisbane to discuss the current status and future directions of dung beetle activities in Australia. This meeting led to the formation of the National Dung Beetle Steering Committee, chaired by Mick Alexander. A proposal was developed by this committee, with widespread support, for a dung beetle project to be undertaken in Queensland. In October 2000 a two-year project was funded by the Natural Heritage Trust, with AgForce as the lead agency, and with state government support through the Queensland Beef Industry Institute (DPI), the Environmental Protection Agency and the Department of Natural Resources and Mines.

The major objective of the project was to conduct a survey of the distribution and abundance of dung beetles across Queensland. Following this, appropriate introduced species were to be selected for harvesting and redistribution. Thus the project was entitled "Improving sustainable land management systems in Queensland using dung beetles", and was undertaken between January 2001 and December 2002.

The vision of the project was "The whole community growing in knowledge and support of the value of dung beetles as improvers of landscape health, sustainable land stewardship, and people's environment".

ii) Outline of project

The 2001-2002 Queensland Dung Beetle Project had three main objectives:

- To survey and monitor the current distribution and abundance of dung beetle species in cattle dung throughout Queensland

- To train 1,000 landholders in dung beetle identification, biology and population management, and to educate them in the benefits of dung beetles for farm productivity and environmental sustainability

- To redistribute dung beetle species to climatically suitable areas requiring population enrichment.

This report presents details on the results of the dung beetle survey, and a summary of outcomes of the other two activities.

iii) Project structure

The project was overseen by a Project Management Committee, made up of members from AgForce (Richard Golden, Chair), three landholder/Landcare representatives (Bruce Lord, Murray Gibson, Greg Weekes), a scientific representative (Angus Macqueen), and representatives from Queensland Beef Industry Institute, Environmental Protection Agency and Natural Resources and Mines. The Project Manager was Mick Alexander, who also served on the Committee.

The project team comprised a Technical Co-ordinator (Penny Edwards), and four DPI extension officers (Graeme Elphinstone [DPI Project Team Leader], Jill Aisthorpe, Gavin Graham and David Smith).

The objectives of the dung beetle survey were to be met by establishing at least 100 monitoring sites around Queensland. To facilitate this process, the state was divided into four regions. The four DPI extension officers were responsible for developing a network of volunteer landholders in their own regions, to establish traps on landholders' properties and provide instruction and ongoing support.

A tri-fold brochure was prepared (Figure 1) to provide the public with information on the aims, funding and structure of the project.

iv) Survey methods

Two pitfall traps were established at each monitoring site. The traps were set for 24 hours, once a month for twelve months. The traps were baited with 1 litre of fresh cow dung, wrapped in gauze. The traps were set in the morning (or late afternoon), and the dung bait replaced with a fresh bait the following afternoon (or morning). After 24 hours, the traps were cleared, the beetles killed and dried, and sent to the project team for identification and counting. Native dung beetles were sent to Ross Storey, DPI Mareeba, for identification.

Landholders who assisted with the trapping program were supplied with all the equipment and supplies that were required, as well as a copy of "Common Dung Beetles in Pastures of south-eastern Australia" by Marina Tyndale-Biscoe (1990).

Figure 1. Tri-fold brochure providing general information about the Queensland Dung Beetle Project

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Monitoring your beetles

- Look for dung pads one or two days old.
- Approach quietly, as dung beetles are sensitive to vibrations.
- Shovel up two dung pads into a bucket with 10 litres of water, taking about 25 mm of topsoil from below the pad.
- Stir with a shovel to break up the pads.
- Scoop off floating dung beetles and place a couple of samples of each different beetle in a jar and kill with hot water. Release remainder back to dung pads.
- Dry the beetles for 2-3 days on a sheet of newspaper or paper towel.
- Place beetles into a match box and label with date and location.
- Bring your specimens along to the dung beetle training days to be organised across Queensland.

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the Queensland Dung Beetle project

aims

- Reduced fly numbers
- Improved soil quality
- Decreased run-off
- Improved nutrient recycling

Queensland Government

"Dung today, gone tomorrow"

How dung beetles work for you

By rapidly burying dung pads, dung beetles reduce fly breeding sites and therefore fly numbers. Dung burial also reduces the infective stages of gastro-intestinal parasites of livestock. Dung beetles clean up pastures and return nutrients to the soil. The beetles' tunnels result in greater water retention, less run-off, improved root penetration and soil aeration.

The benefits of having an active dung beetle population are:

- greatly reduced buffalo fly and bush fly populations when beetles are active;
- improved soil health and structure;
- improved soil-water infiltration and nutrient recycling.

Dung beetles in Australia

Most Australian dung beetles don't cope well with the dung of introduced animals. As a result, cattle dung is not efficiently broken down by these native beetles.

CSIRO introduced dung beetle species into Australia from Africa and Europe in an attempt to improve dung burial and thereby reduce fly numbers. 43 species were released throughout Australia during the 1970s and early 1980s. Of the 29 exotic species released in Queensland, eight are widely established, and the status of the remainder is unknown.

Current situation

Some species released in Queensland are still in the establishment or dispersal phase with many potential climatic niches yet to be filled. Many areas require a greater diversity of species to achieve optimal dung burial. For maximum burial from spring to autumn it is desirable to have several species of dung beetles with complementary periods of activity.

Our Mission

To achieve optimal dung burial, buffalo fly and bush fly control and environmental benefits across Queensland through a greater diversity of dung beetle species.

Goals

The project has three stages:

- Survey and monitor the current distribution of dung beetle species.
- Develop and train a network of landholders in dung beetle collection, identification and ongoing monitoring.
- Source and relocate dung beetle species to climatically suitable areas requiring population enrichment and educate the broad community about the benefits of dung beetles.

This project

The project will run over two years. Funding and support has been provided by the Natural Heritage Trust, DPI's Agency of Food and Fibre Sciences, Environmental Protection Agency, AgForce Queensland and Queensland landholders.

Governing body

The project activities and funding will be overseen by a Project Management Committee.

Members:
Richard Golden, AgForce representative, Chair
Bruce Lord, landholder/landcare, south Qld
Murray Gibson, landholder/landcare, central Qld
Greg Weekes, landholder/landcare, north Qld
Angus Macqueen, Scientific representative
Andrew Bourne, Queensland Beef Industry Institute
Shauna Dewhurst, Environmental Protection Agency
Bill Palmer, Department of Natural Resources
Mick Alexander, Project Manager

Project team

The project team is composed of four QBII Extension Officers (one each in north, central, south and south-east Queensland) and a Technical Coordinator (ex CSIRO Division of Entomology) based in south-east Queensland.

Figure 2. Location of Queensland Dung Beetle Project trapping sites

v) Trapping sites

Traps were established at 123 sites. In three areas, results from trapping sites that were in very close proximity were combined for the purposes of mapping beetle distributions. These are Dingo (two sites combined), Wowan (three sites combined) and Rolleston 2 (two sites combined). The resulting 119 sites are shown in Figure 2.

Trapping sites have been given locality names in Figure 2 and throughout this report, rather than property names. Each landholder involved in the trapping program has been notified of the locality name of their site, so will be able to identify it on Figure 2, and throughout this report.

The name allocated to each site refers to a town that is generally the closest town to the site, or reflects the postal address of the property. In some cases, particularly in more remote areas of the state, the trapping site may be some distance from the town indicated. For instance, "Winton 2" is 200 km from Winton.

vi) Climatic averages at trapping sites

Trapping sites were established over a wide range of climatic conditions. The main climatic factors affecting the distribution of dung beetles are rainfall (total annual amount, and season of rainfall) and temperature (annual and monthly maxima, minima and averages).

Mean annual rainfall for Queensland is shown in Figure 3a, with the trapping sites superimposed. Sites were located in all rainfall zones, ranging from Bedourie with an annual rainfall of approximately 250 mm, to Tully with approximately 4,000 mm.

The average annual maximum temperatures for Queensland are shown in Figure 3b, with the trapping sites superimposed. The coolest zone is where average maximum temperatures range between 21^{o}C and 24^{o}C, and includes sites such as Numinbah Valley, Stanthorpe, Highfields, Maleny, Crows Nest and Eungella. The warmest zone experiences average maximum temperatures of between 33^{o}C and 36^{o}C, and includes sites such as Normanton, Georgetown 1 and 2, Croydon, Julia Creek 2 and Richmond 2 and 3.

Annual rainfall increases in a SW to NE direction, whereas average maximum temperature increases in a SE to NW direction. This results in a wide array of rainfall and temperature combinations throughout the State.

Figure 3a Average annual rainfall in Queensland

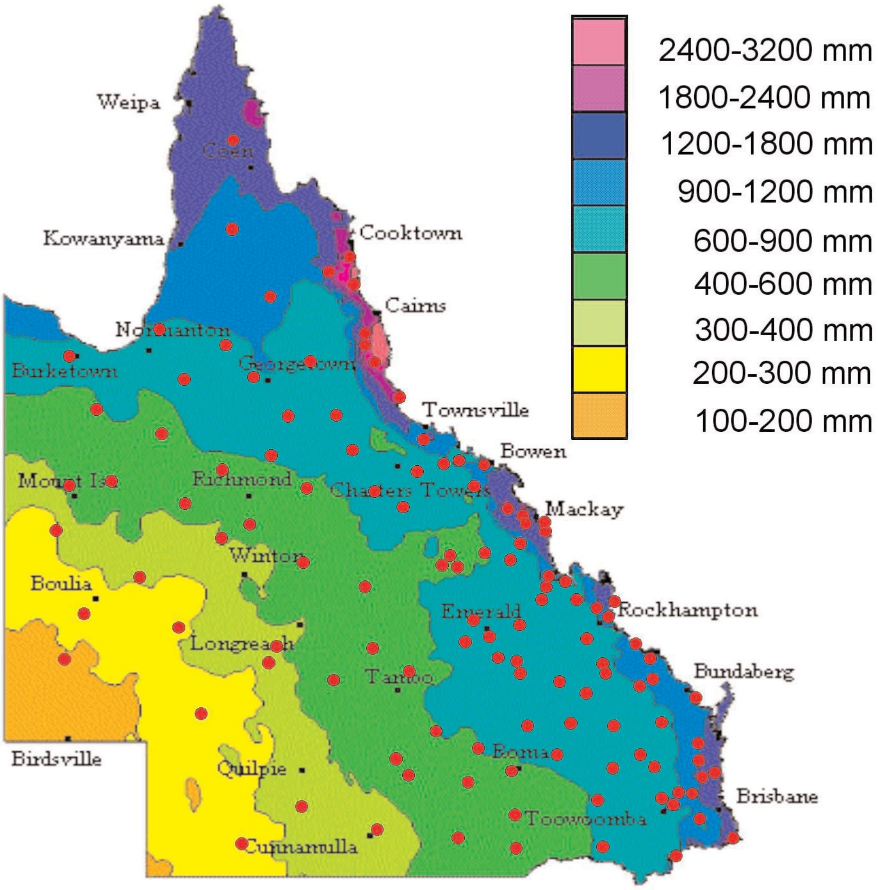
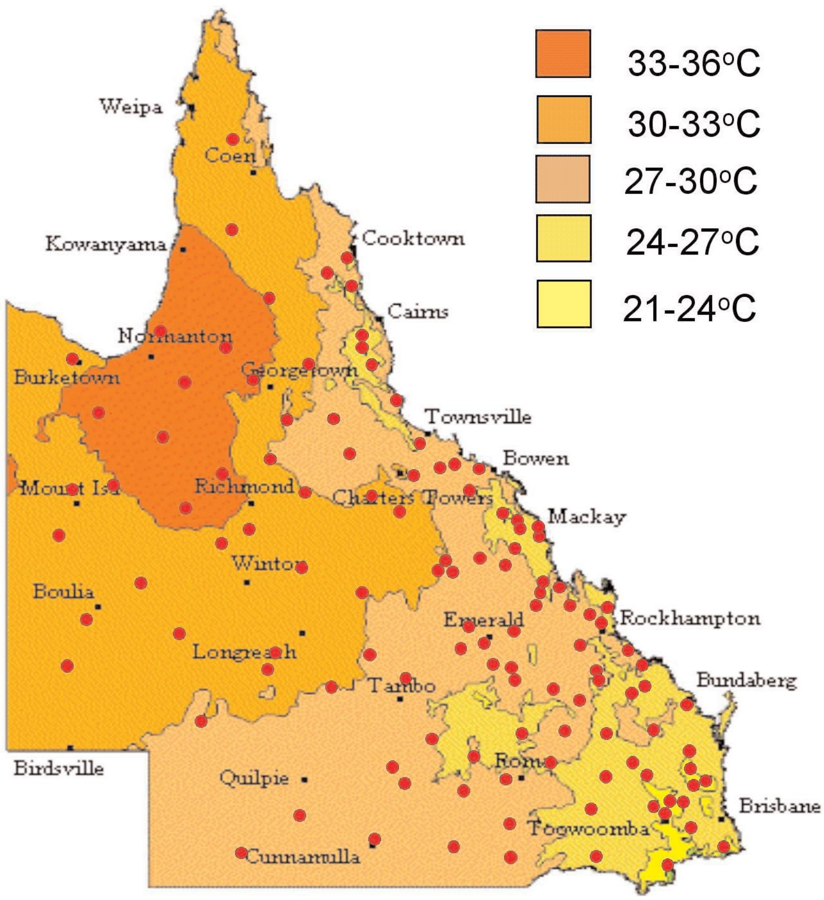


Figure 3b Average annual maximum temperature in Queensland



2. RESULTS OF DUNG BEETLE SURVEY

i) Weather conditions during the project

The first samples were collected in February 2001, and the last in July 2002. This period was characterised in most regions by below-average rainfall. Figure 4 shows the deviations from normal rainfall in three-month periods from February 2001 to July 2002. Areas shaded grey received average rainfall (± 20%). Areas shaded yellow and orange areas received below average rainfall, and areas shaded blue and green received above average rainfall.

The main period of dung beetle activity during the project was from November 2001 to April 2002. For the first three months of this period rainfall was average or above average for much of the central area of Queensland, and below average in many coastal areas and the far west and south (Figure 4d). In the second three months, a large part of the state received well below average rainfall, particularly in central and western Queensland and the whole coastal area (Figure 4e).

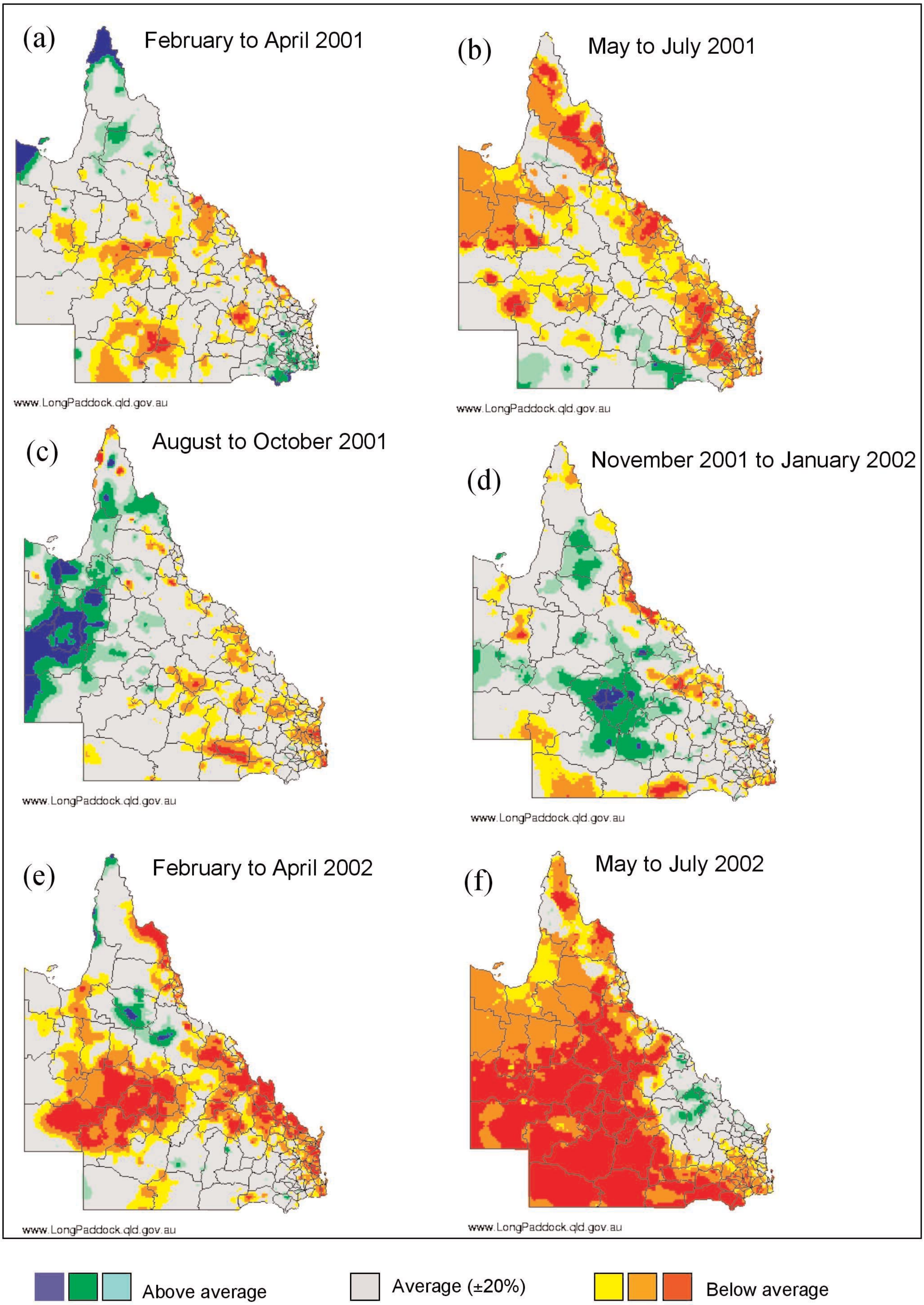
ii) Trapping statistics

a) Collections per site.
At least one sample of dung beetles was collected from each of the 123 sites. The largest number of samples collected at any site was 34 (i.e. two traps set for 17 months), and this occurred at two sites. The smallest number of samples collected was one (i.e. one trap for one month) and this occurred at three sites. The average number of samples collected per site was 17.5.

At the start of the project it was hoped that as many co-operators as possible would be able to collect 24 samples or more (i.e. 2 traps set for 12 months). However it was recognised that landholders' circumstances and work commitments would change during the project, and that the number of collections made would vary considerably. Figure 5 shows the frequency distribution of the number of collections made at each site. This graph shows that the peak in number of samples returned per site occurred at 24 samples (from 18 sites), reflecting the stated goal of trapping for 12 months. Forty-six co-operators (or 37%) collected 24 or more samples, and 50% of co-operators made 20 or more collections, which was an outstanding result. However every sample that was collected was valuable. Any trapping that resulted in no beetles being caught was also a valuable result, and landholders were encouraged to continue trapping through the winter months and to notify of nil returns.

b) Collections per month.
The first trapping sites were established in February 2001, and most sites were in place by May 2001. Seven sites were established in February 2002, to provide additional data from western Queensland. The number of samples returned per month (Figure 6) largely reflects this pattern of site establishment. Between April 2001 and April 2002 inclusive, the average number of samples returned per month was 145 (i.e. 2 traps from 72.5 sites).

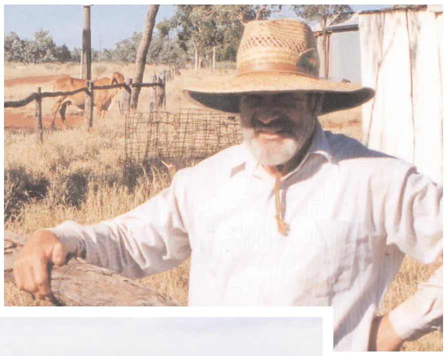
Figure 4. Deviations from normal rainfall from February 2001 to July 2002



iii) Summary of results

A summary of the results of the dung beetle survey follows:

Number of introduced species trapped during project:	15
Number of native species trapped during project:	73
Most introduced species at one site:	12 at Highfields
Most native species at one site:	23 at Mount Surprise
Most dung beetles (introduced and native) caught in one trap:	7,449 at Childers on 3 Feb 02
Most introduced dung beetles caught in one trap:	7,345 at Childers on 3 Feb 02
Most native dung beetles caught in one trap:	6,327 at Richmond 3 on 24 Nov 01



The following two sections present details of the introduced and native dung beetles caught during the project.

Figure 5. Number of dung beetle samples collected on each property

(two traps per trapping occasion = 2 samples)

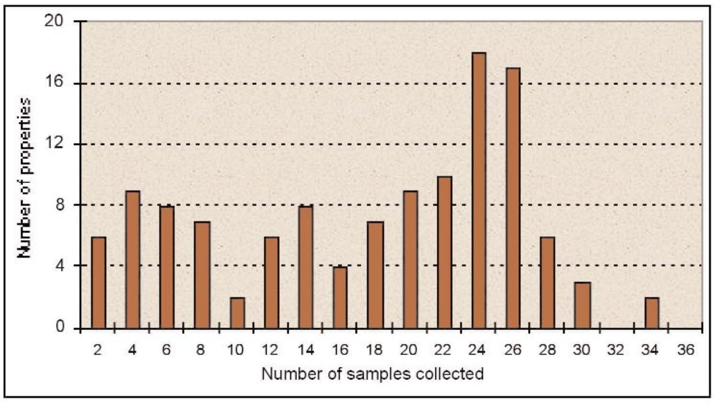
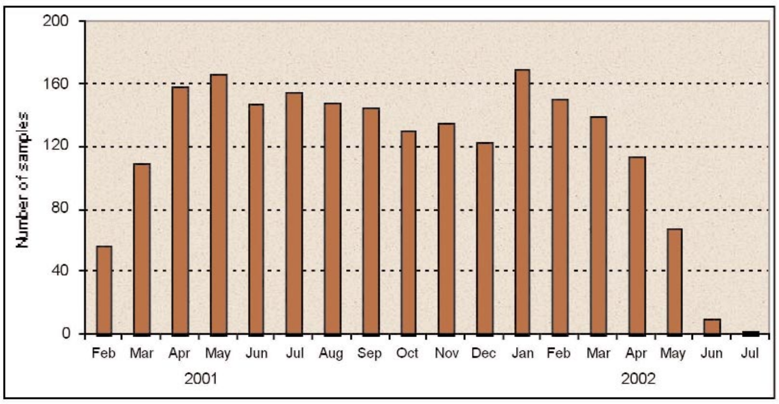


Figure 6. Number of dung beetle samples collected each month throughout Queensland

(two traps per trapping occasion = 2 samples)



3. INTRODUCED DUNG BEETLES

"I arrived in Australia at the end of 1950 with a mission: to do something in my field of expertise that nobody had attempted before: something lasting, something BIG."
(Dr George Bornemissza, personal correspondence).

i) Species of introduced dung beetles collected during the 2001-2002 survey

Dr George Bornemissza conceived the idea of introducing dung beetles into Australia in the early 1950s (Bornemissza 1976). The CSIRO Australian Dung Beetle Project commenced in 1964, and from the late 1960s to early 1980s, 43 species of dung beetles were introduced into Australia from Africa and Europe. Twenty-nine species were introduced into Queensland, mostly from Africa.

During the 2001–2002 Queensland Dung Beetle Project, fifteen species of introduced dung beetles were collected. Two colour sheets were prepared to assist in identification of these species. The first, "Common Dung Beetles in Queensland", is shown in Figure 7. The second, "More Dung Beetles in Queensland", is shown in Figure 8.

Table 1 presents a summary of these species, with the most widespread listed first. A total of 2,128 samples was collected (usually 2 samples each site per month). A 'sample' is the catch from one trap. The number of samples in which a species was found is shown in column 3 (the maximum possible number is 2,128). The size of each species is indicated (columns 4 and 5) to facilitate comparison with the native beetles (next section)

Results on the distribution, abundance and seasonality of each introduced species are presented on the following pages (Figure 9a – o).

A **distribution** map is presented for each species. Solid circles indicate sites where the species was collected, empty circles indicate sites where the species was not collected. The name of each trapping site can be determined from Figure 2. For a few species, additional distribution information is provided, particularly where this provides a significant extension to the known range. This additional information came either from samples sent in for identification following Dung Beetle Training Days, or from samples collected by staff during the course of the project.

Data on **abundance** of each species are presented in two ways. (i) Details of the largest trap catches are provided, so that landholders can make a simple comparison with their own results, and gauge how their samples compare with the largest achieved in the state. With some of the really large catches, beetles were so numerous that the funnel became blocked and additional beetles escaped. (ii) Data are presented on the "average trap catch throughout the year" from individual sites. This is to enable comparison between sites, where the number of trapping occasions may have been different. These figures are calculated from the total number of beetles of a particular species that was trapped at one site, divided by the number of times traps were set at that site. There may be some bias in this method, particularly if trapping was done more frequently at one time of year than another. However it was decided this was the most straightforward method to facilitate comparisons between sites. Sites with the highest average trap catches indicate sites where the species is most abundant and hence areas which are the most suitable for the species. Sites with the lowest average trap catch indicate sites where the species is least abundant, and hence areas that are probably marginal for the species in terms of climate or habitat.

A graph is presented to indicate the seasonality of each species. These graphs were derived by dividing the total number of beetles caught each month throughout the state, by the number of times traps were set that month. For each species, only sites at which that species was known to occur were used in the analysis. For instance, only the 26 sites at which *Onthophagus sagittarius* occurred were used to derive the monthly averages for that species. If no traps were set in a particular month for any species a gap appears in the graph (with no symbol on the x-axis). This is to distinguish between months with an average trap catch of zero (in which case a symbol [◆] appears on the x-axis).

Table 1. Summary of introduced dung beetle species trapped during the 2001-2002 Queensland Dung Beetle Project

Species	Number of sites where species was found	Number of samples in which species was found	Size of beetles	Range in body length of beetles (mm)
Onthophagus gazella	119	1471	Medium	10-13
Euoniticellus intermedius	118	1758	Small	7-9
Onitis alexis	92	585	Large	13-19
Sisyphus rubrus	80	923	Small	6-8
Liatongus militaris	77	828	Medium	8-10
Onitis viridulus	69	246	Large	18-23
Sisyphus spinipes	68	540	Medium	8-10
Onthophagus sagittarius	26	277	Medium	8-10
Euoniticellus africanus	15	86	Medium	8-13
Onthophagus nigriventris	7	58	Medium	10-12
Onthophagus binodis	3	27	Medium	11-13
Onitis pecuarius	3	17	Large	15-20
Copris elphenor	2	3	Very large	20-25
Onitis caffer	2	13	Large	15-20
Onitis vanderkelleni	1	9	Large	15-20

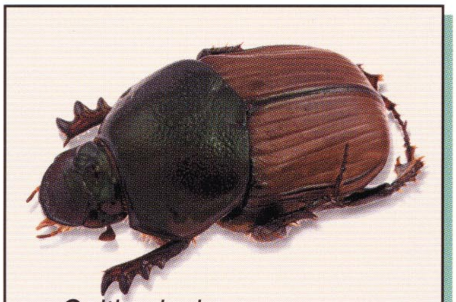



Figure 7

Queensland **Dung Beetle** project

Common Dung Beetles in Queensland

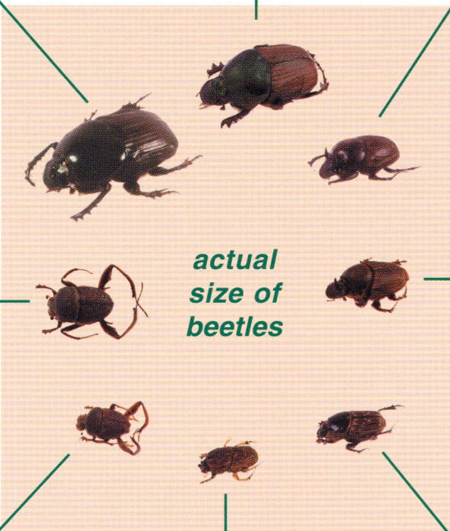
Onitis viridulus
- Large beetle, uniform dark metallic green/black
- Male with unequal double spur on hind leg



Onitis alexis
- Large beetle, two-tone colour (thorax green/red, wing-covers brown)
- Male with single 'rose-thorn' spur on hind leg
- Female with small 'bump' at rear of head

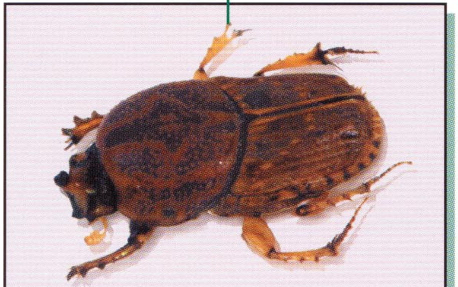
Onthophagus gazella
- Medium beetle, two-tone colour (thorax dark brown, wing-covers lighter brown)
- Rounded shape when viewed from above
- Male with a pair of horns at back of head

Sisyphus spinipes
- Medium dark brown/black beetle with long legs
- Male with dark spur at base of hind leg
- Male with sharp angle on rear of hind leg



Onthophagus sagittarius
- Medium/small beetle, uniform bronze/ brown colour
- Male with two small horns at front of head
- Female with single horn on head and single horn on thorax

Sisyphus rubrus
- Small light brown beetle with long legs
- Male with pale spur at base of hind leg
- Male with rounded rear edge on hind leg



Euoniticellus intermedius
- Small beetle, elongated narrow shape, yellow/brown colour
- Faint diamond-shaped pattern on thorax
- Male with blunt horn on head

Liatongus militaris
- Small beetle, overall colour dark brown/black
- Pale yellow 'shoulder pads' (on sides of thorax)
- Black broken stripes on wing-covers

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Figure 8

More Dung Beetles in Queensland

Onthophagus nigriventris

- Medium beetle, head & thorax black/green, wing covers brown, under-surface shiny black
- Both sexes have small lobe at front of thorax
- Large males with long horn on thorax, projecting from beneath the lobe to over the head

Onitis caffer

- Large beetle, sturdy appearance, uniform shiny black
- Wing covers with distinct longitudinal ridging
- Male with serrated ridge on hind leg (no spur)

Copris elphenor

- Very large beetle, uniform shiny black colour
- Male with large tapered horn on head
- Female with small blunt horn on head

Onthophagus binodis

- Medium beetle, uniform matt black
- Lobe at front of thorax, usually larger in males

Euoniticellus africanus

- Small narrow beetle, yellow/brown colour (slightly larger than *E. intermedius*)
- Two shiny black spots mid thorax
- Neither sex has a horn on the head

actual size of beetles and male leg structure of Onitis species

Onitis pecuarius

- Large beetle, uniform dark brown/black
- Male with unequal double spur on hind leg
- Very similar to *O. viridulus*, but slightly stockier and lacking metallic green sheen

Onitis vanderkelleni

- Large beetle, uniform dark brown/black
- Male with single straight spur on hind leg
- Female with distinct round bump at back of head

For further information contact:
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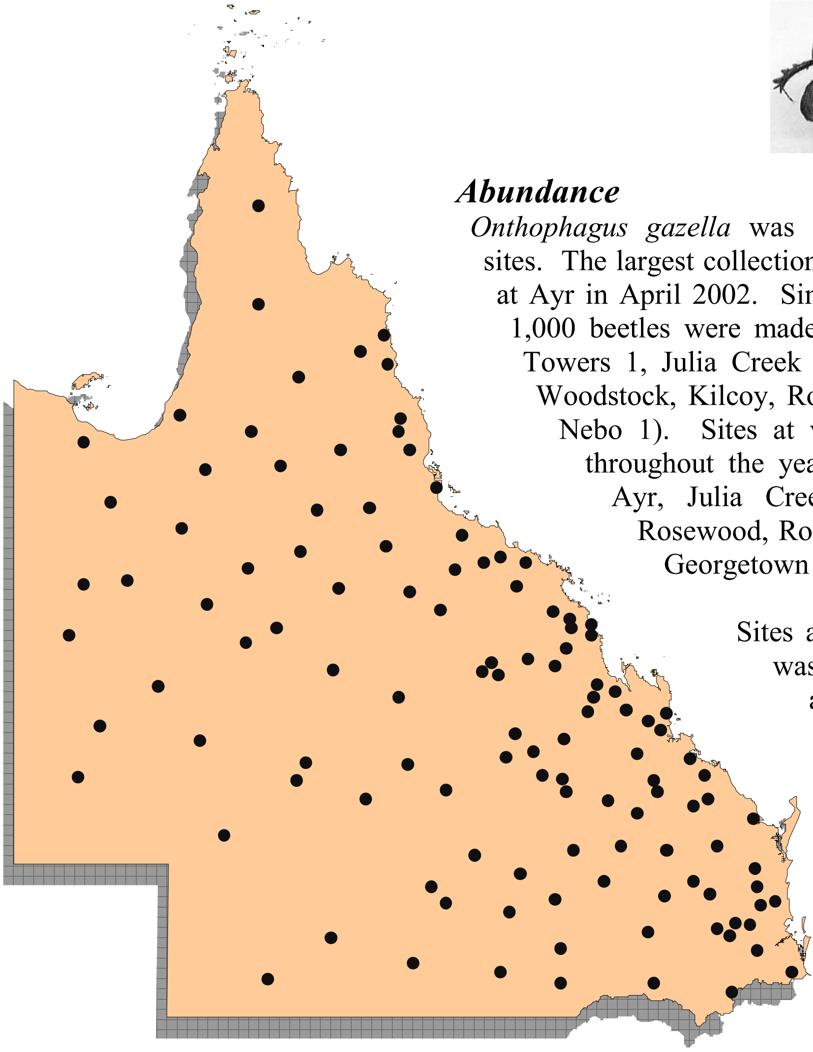
Onthophagus gazella

Distribution

Onthophagus gazella was the most widespread introduced dung beetle, and was trapped at all 119 sites.



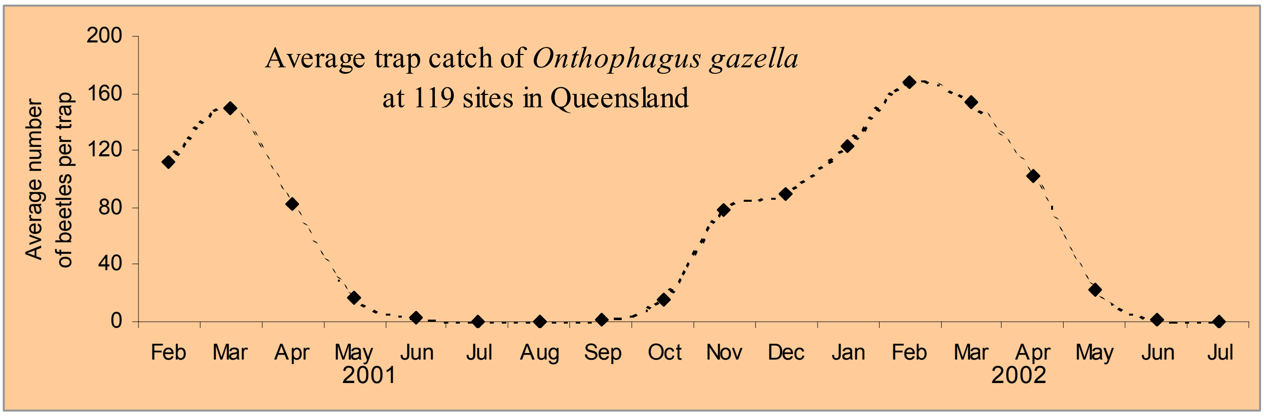
Abundance

Onthophagus gazella was extremely abundant at many sites. The largest collection in one trap was 3,511 beetles at Ayr in April 2002. Single trap catches of more than 1,000 beetles were made at nine other sites (Charters Towers 1, Julia Creek 1 [twice], Rosewood [twice], Woodstock, Kilcoy, Roma, Blackall 1, Sapphire and Nebo 1). Sites at which the average trap catch throughout the year exceeded 135 beetles were Ayr, Julia Creek 1, Woodstock, Sapphire, Rosewood, Rolleston 1, Emerald, Mount Isa, Georgetown 2, Blackwater and Chinchilla.

Sites at which *Onthophagus gazella* was least abundant, with an average trap catch of under 6 beetles, were Ravenshoe, Eungella, Malanda, Numinbah Valley, Stanthorpe, Daintree and St Lawrence. These sites, with the exception of Stanthorpe, are characterised by high average rainfall.

Seasonality

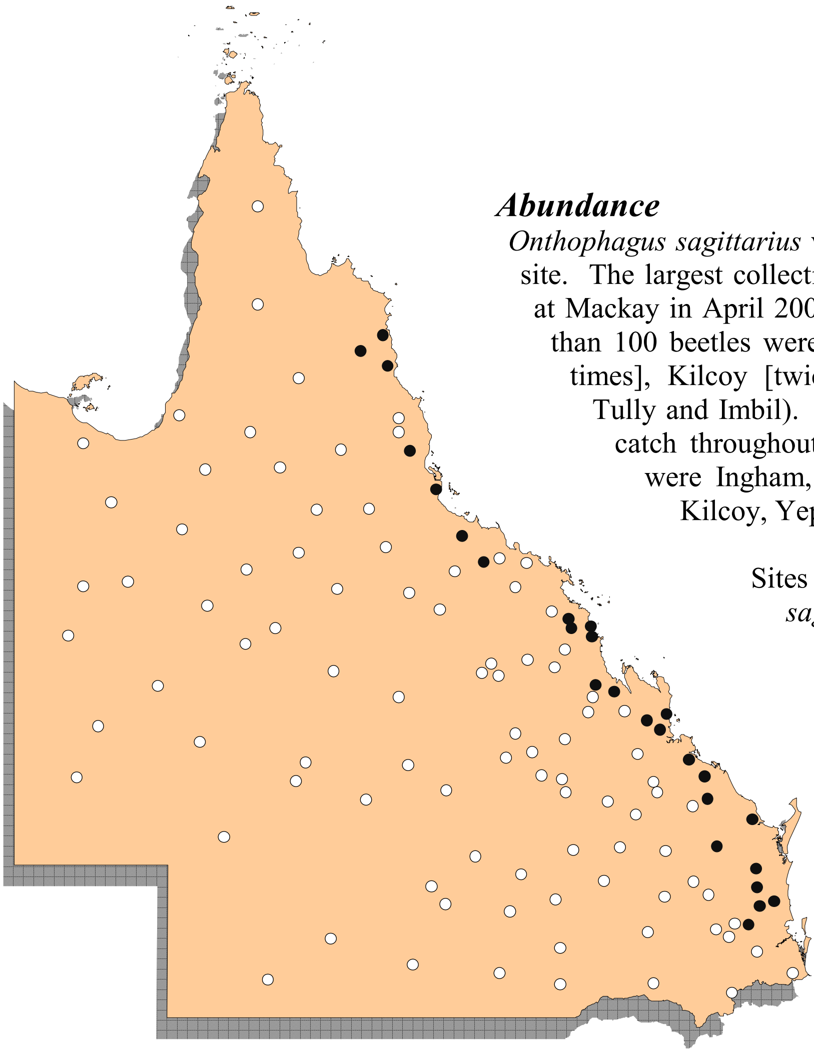
Onthophagus gazella was abundant between November and April. Numbers were highest in February and March. Activity was virtually nil between June and September. The highest monthly average was 168 beetles in February 2002.

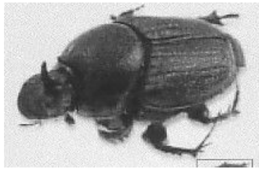


Onthophagus sagittarius

Distribution

Onthophagus sagittarius was trapped at 26 sites, mostly within 100 km of the east coast of Queensland. It was not trapped at the Ravenshoe or Malanda site, however samples were received after Training Days from Tolga, Mt Molloy, Kairi and Yungaburra.





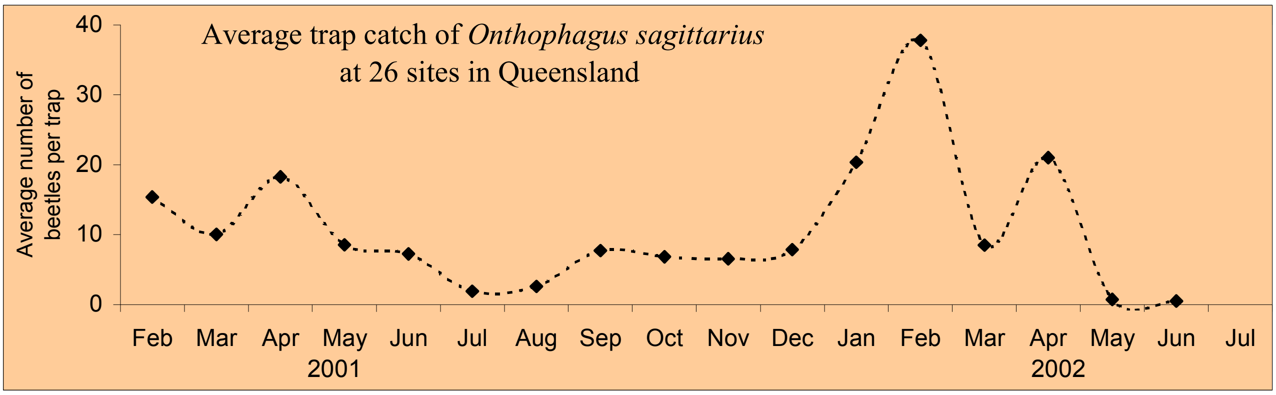
Abundance

Onthophagus sagittarius was never very abundant at any site. The largest collection in one trap was 294 beetles at Mackay in April 2002. Single trap catches of more than 100 beetles were made at six sites (Mackay [4 times], Kilcoy [twice], Childers, Ingham [twice], Tully and Imbil). Sites at which the average trap catch throughout the year exceeded 20 beetles were Ingham, Mackay, Childers, Cooktown, Kilcoy, Yeppoon, Sarina and Nebo 3.

Sites at which *Onthophagus sagittarius* was least abundant, with an average trap catch for the whole year of fewer than two beetles, were Koumala, Ogmore, St Lawrence, Esk, Lakeland and Gayndah. The records from Lakeland and Gayndah each comprised a single beetle.

Seasonality

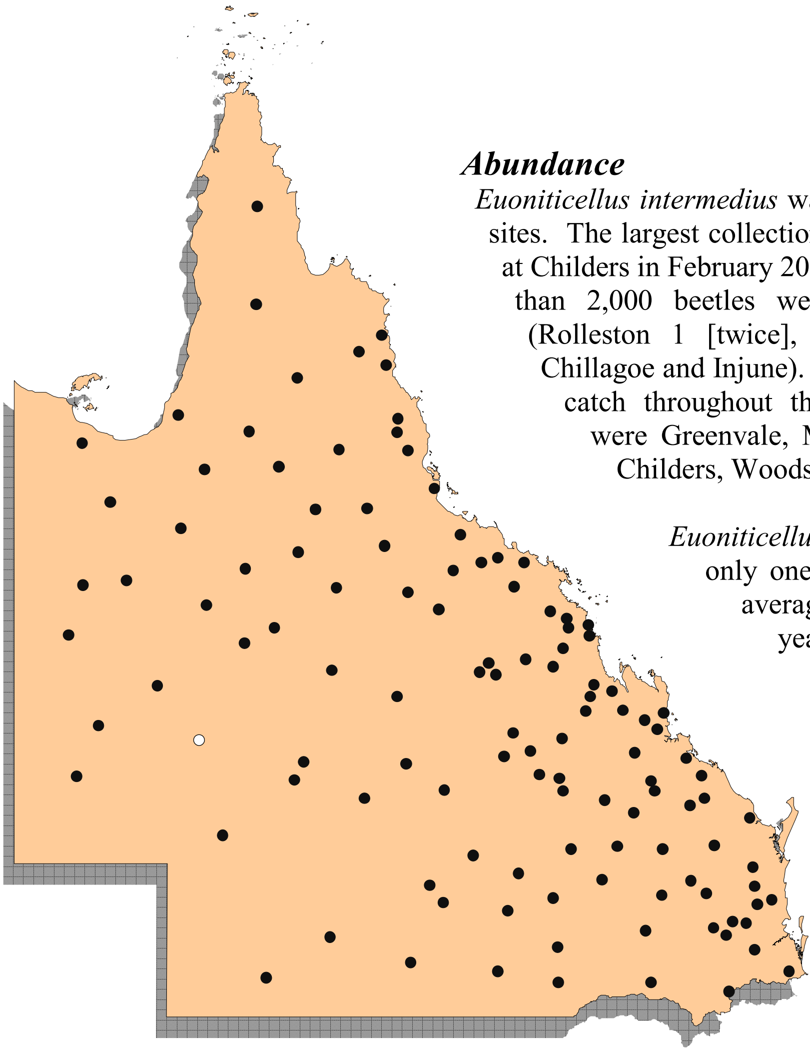
Onthophagus sagittarius was most abundant in February and April in both years, and least abundant in July and August 2001 and May and June 2002. The highest average trap catch was 38 beetles in February 2002.

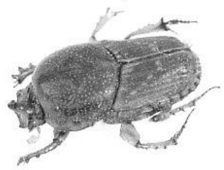


Euoniticellus intermedius

Distribution

Euoniticellus intermedius was widespread throughout Queensland, and was trapped at 118 of the 119 sites.





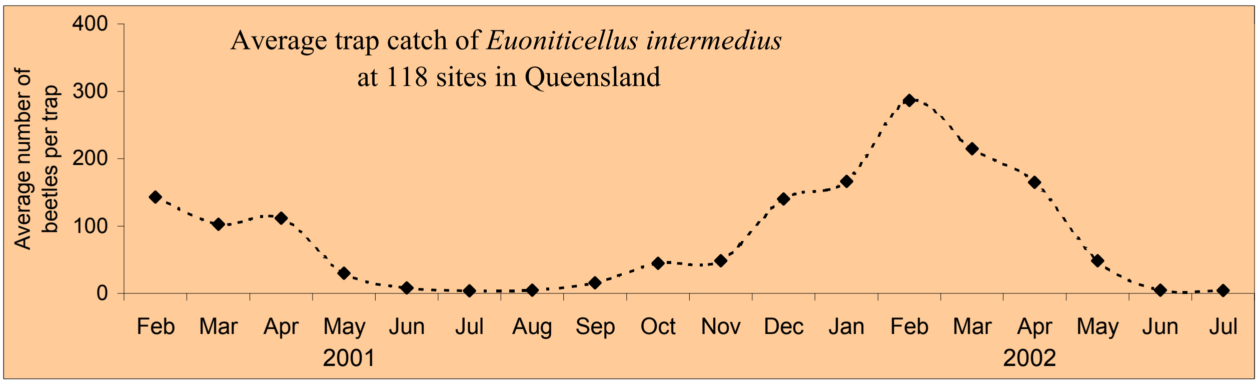
Abundance

Euoniticellus intermedius was extremely abundant at many sites. The largest collection in one trap was 5,558 beetles at Childers in February 2002. Single trap catches of more than 2,000 beetles were made at five other sites (Rolleston 1 [twice], Greenvale [twice], Sapphire, Chillagoe and Injune). Sites at which the average trap catch throughout the year exceeded 250 beetles were Greenvale, Moura, Thangool, Rolleston 1, Childers, Woodstock, Ayr, and Injune.

Euoniticellus intermedius was absent from only one site, Winton 2. Sites with an average trap catch throughout the year of fewer than 2 beetles were Richmond 1, Malanda, Ravenshoe, Koumala, Longreach 2, Numinbah Valley, Burketown 1, Boulia 1 and Bedourie. Most of these sites are among either the wettest or driest sites in the state.

Seasonality

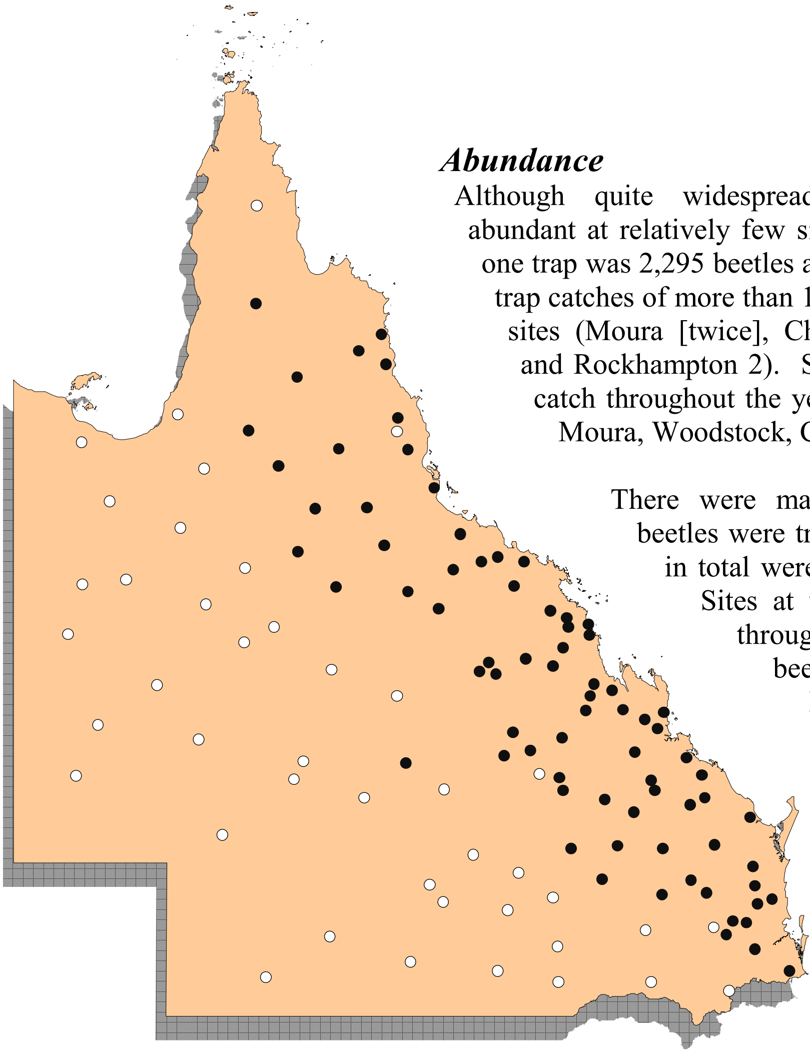
Euoniticellus intermedius was present in nearly all months. Numbers were highest in February, and lowest from June to August. The highest average trap catch was 286 beetles recorded in February 2002.

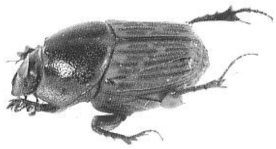


Liatongus militaris

Distribution

Liatongus militaris was trapped at 77 sites in the eastern half of Queensland.





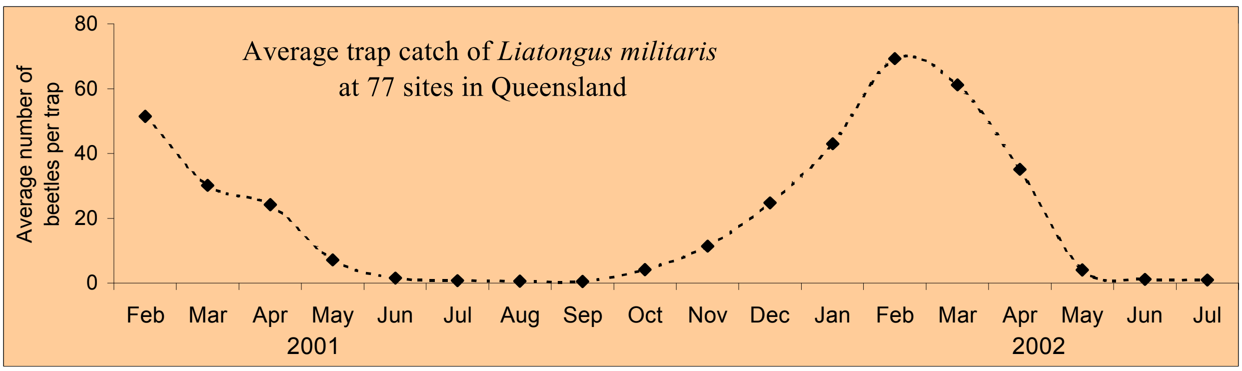
Abundance

Although quite widespread, *Liatongus militaris* was abundant at relatively few sites. The largest collection in one trap was 2,295 beetles at Moura in April 2002. Single trap catches of more than 1,000 beetles were made at five sites (Moura [twice], Childers, Woodstock, Thangool and Rockhampton 2). Sites at which the average trap catch throughout the year exceeded 100 beetles were Moura, Woodstock, Childers and Rolleston 1.

There were many sites where only a few beetles were trapped. Fewer than 40 beetles in total were collected at each of 24 sites. Sites at which the average trap catch throughout the year was less than 0.5 beetles were Taroom, Highfields, Dingo, Georgetown 2, Malanda, Tully, Daintree, Numinbah Valley, Hughenden, Eungella, Blackall 1 and Georgetown 1. Only one specimen was caught at each of these last four sites.

Seasonality

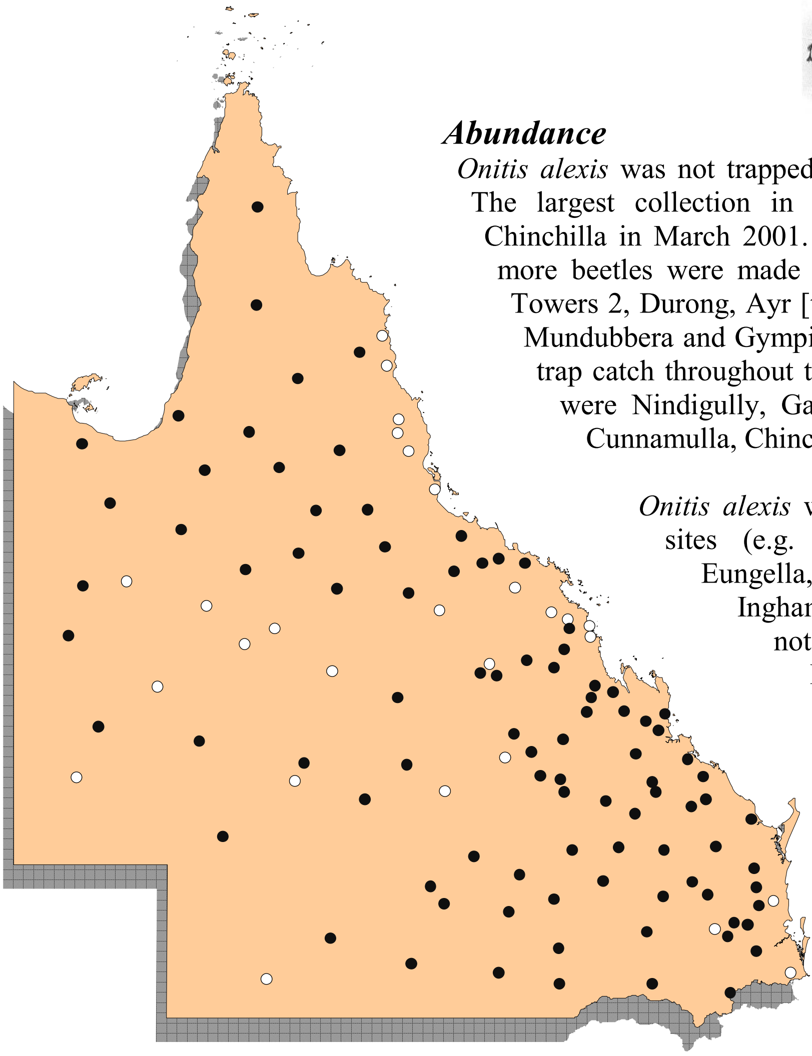
Average numbers of *Liatongus militaris* were highest in February and March, and very low from May to October. The largest average trap catch of 69 beetles occurred in February 2002



Onitis alexis

Distribution

Onitis alexis was very widespread, and was trapped at 92 sites throughout Queensland.



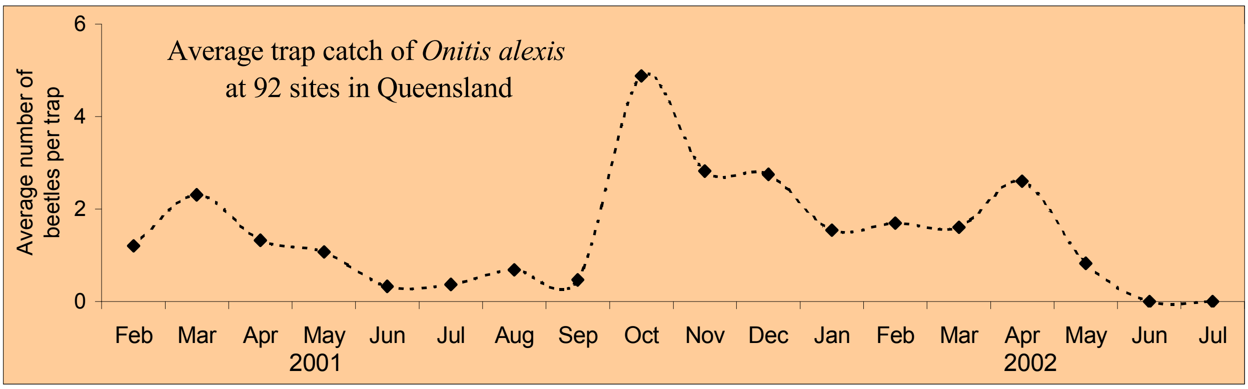
Abundance

Onitis alexis was not trapped in large numbers at any site. The largest collection in one trap was 80 beetles at Chinchilla in March 2001. Single trap catches of 40 or more beetles were made at seven other sites (Charters Towers 2, Durong, Ayr [twice], Nindigully, Stanthorpe, Mundubbera and Gympie). Sites at which the average trap catch throughout the year was 5 or more beetles were Nindigully, Gayndah, Durong, Mundubbera, Cunnamulla, Chinchilla, Ayr and Charleville 2.

Onitis alexis was not trapped at the wettest sites (e.g. Numinbah Valley, Maleny, Eungella, Mackay or sites between Ingham and Cooktown). It was also not trapped on the northern Mitchell grasslands (e.g. Winton 2 and Richmond 2). Sites at which an average of fewer than 0.12 beetles were caught throughout the year were Marlborough 2, Richmond 2, Gumlu, Nebo 3, Highfields, Longreach 1, Clermont 1 and Clermont 3.

Seasonality

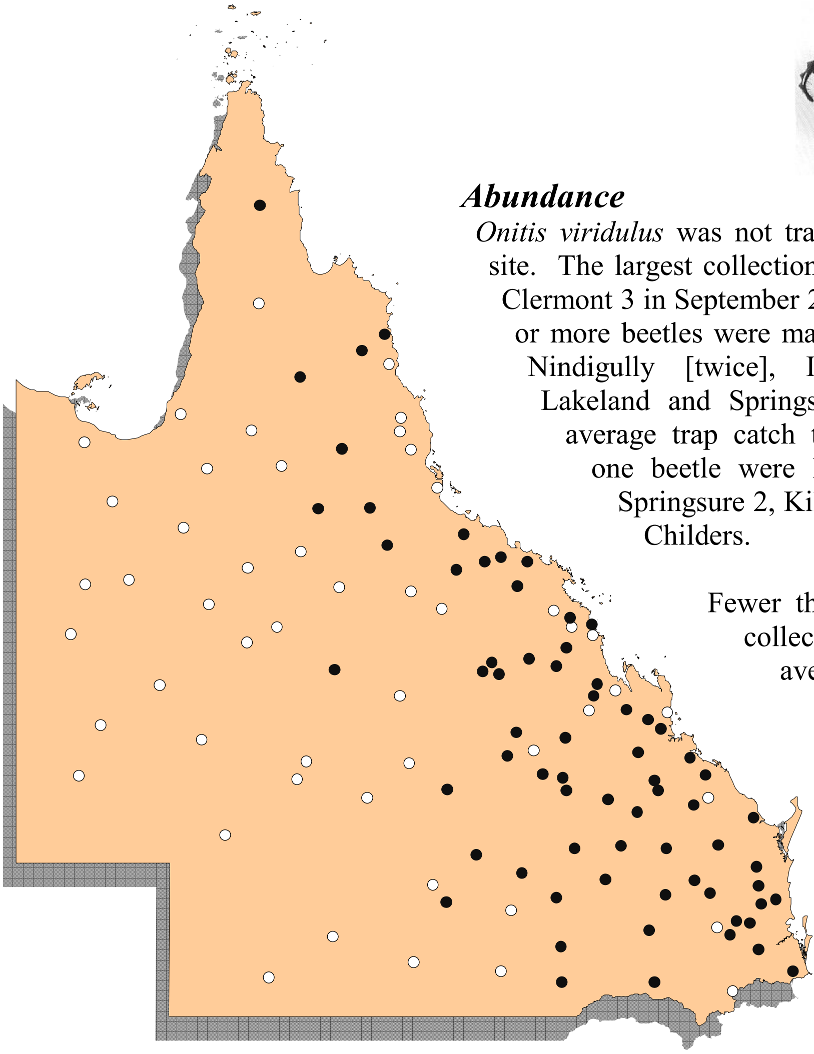
There was a peak in numbers of *Onitis alexis* caught in October and a second smaller peak in March/April. The peak of adults in autumn is likely to be the progeny of adults that bred in spring or early summer. *Onitis alexis* can over-winter in both the adult and larval stage.

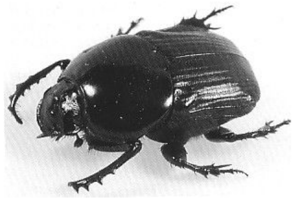


Onitis viridulus

Distribution

Onitis viridulus was trapped at 69 sites in Queensland.





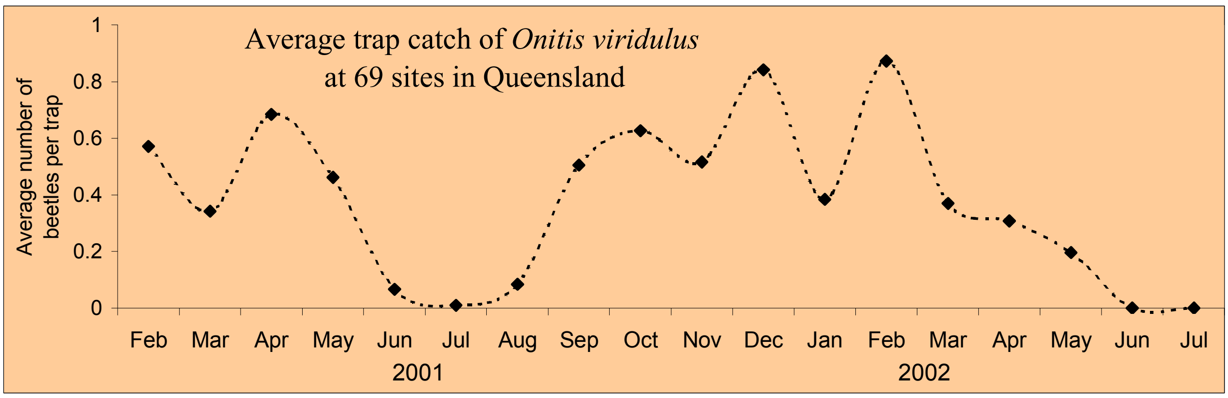
Abundance

Onitis viridulus was not trapped in large numbers at any site. The largest collection in one trap was 23 beetles at Clermont 3 in September 2001. Single trap catches of 10 or more beetles were made at seven sites (Clermont 3, Nindigully [twice], Imbil, Mundubbera, Kilcoy, Lakeland and Springsure 2). Sites at which the average trap catch throughout the year exceeded one beetle were Imbil, Nindigully, Cooktown, Springsure 2, Kilcoy, Clermont 1 Lakeland and Childers.

Fewer than four beetles in total were collected at 26 sites. Sites with an average trap catch throughout the year of under 0.07 beetles were Nebo 1, Marlborough 2, St Lawrence, Gumlu, Miriam Vale, Mitchell 1, Sapphire and Charleville 2. Only one beetle was trapped at each of these sites.

Seasonality

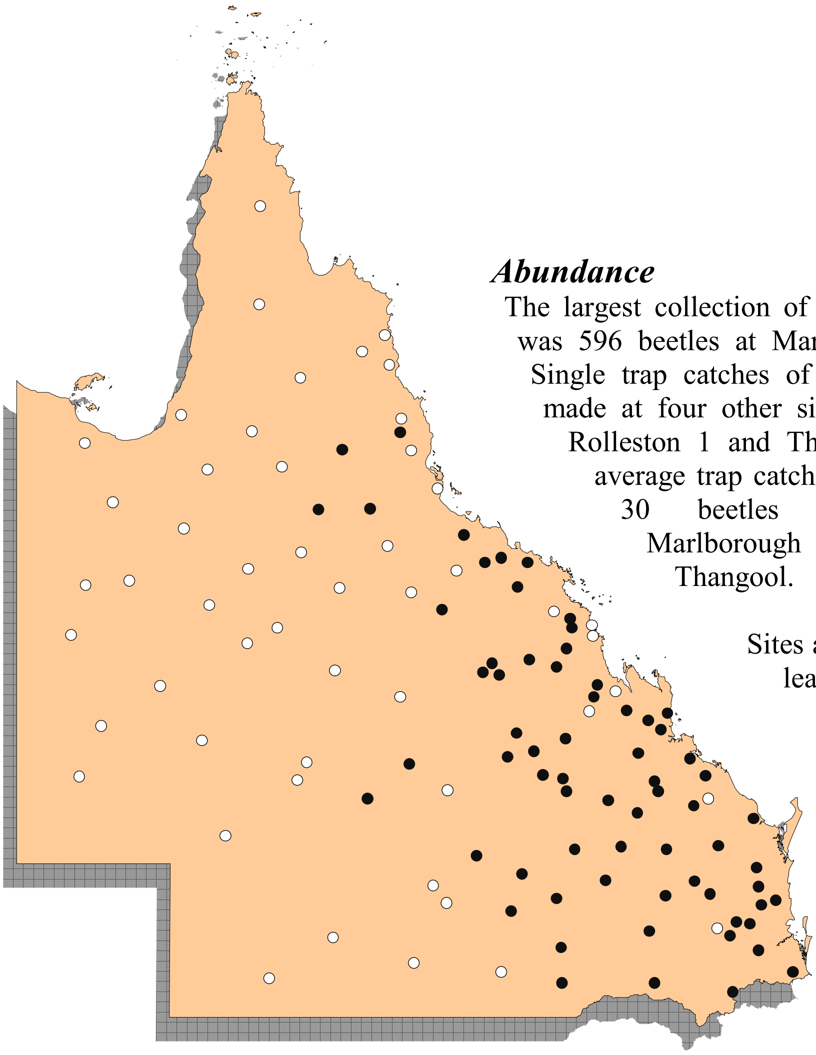
The average trap catch of *Onitis viridulus* was very low throughout the year, being always less than one. Numbers were lowest between June and August, and variable between September and May.

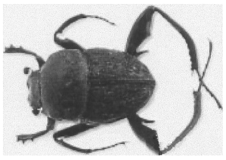


Sisyphus spinipes

Distribution

Sisyphus spinipes was trapped at 68 sites, mostly in the south-eastern part of Queensland.





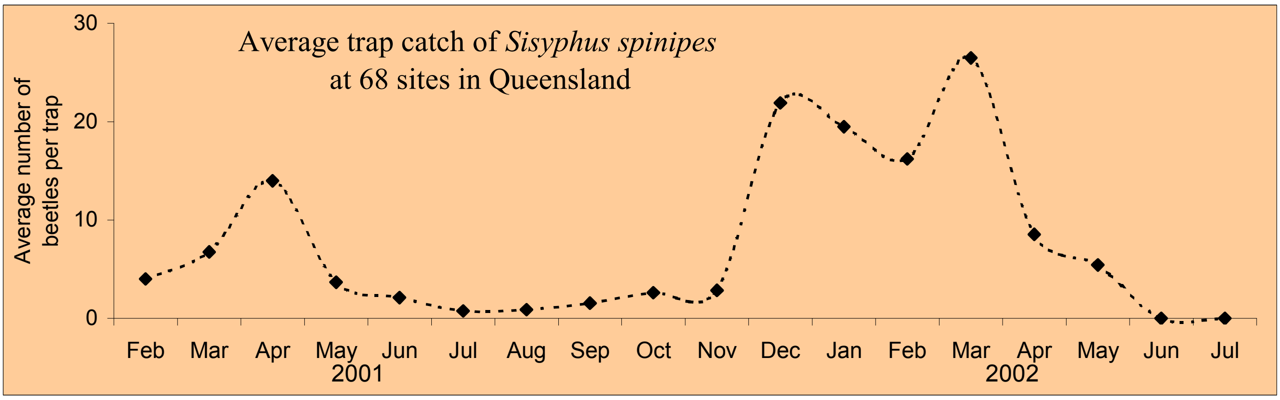
Abundance

The largest collection of *Sisyphus spinipes* in one trap was 596 beetles at Marlborough 2 in January 2002. Single trap catches of more than 300 beetles were made at four other sites (Clermont 2, Clermont 3, Rolleston 1 and Theodore). Sites at which the average trap catch throughout the year exceeded 30 beetles were Moura, Theodore, Marlborough 2, Clermont 3, Durong and Thangool.

Sites at which *Sisyphus spinipes* was least abundant, with an average trap catch throughout the year of fewer than 0.1 beetles, were Crows Nest, Wowan, Stanthorpe, Miriam Vale, Numinbah Valley, Ravenshoe and Maleny.

Seasonality

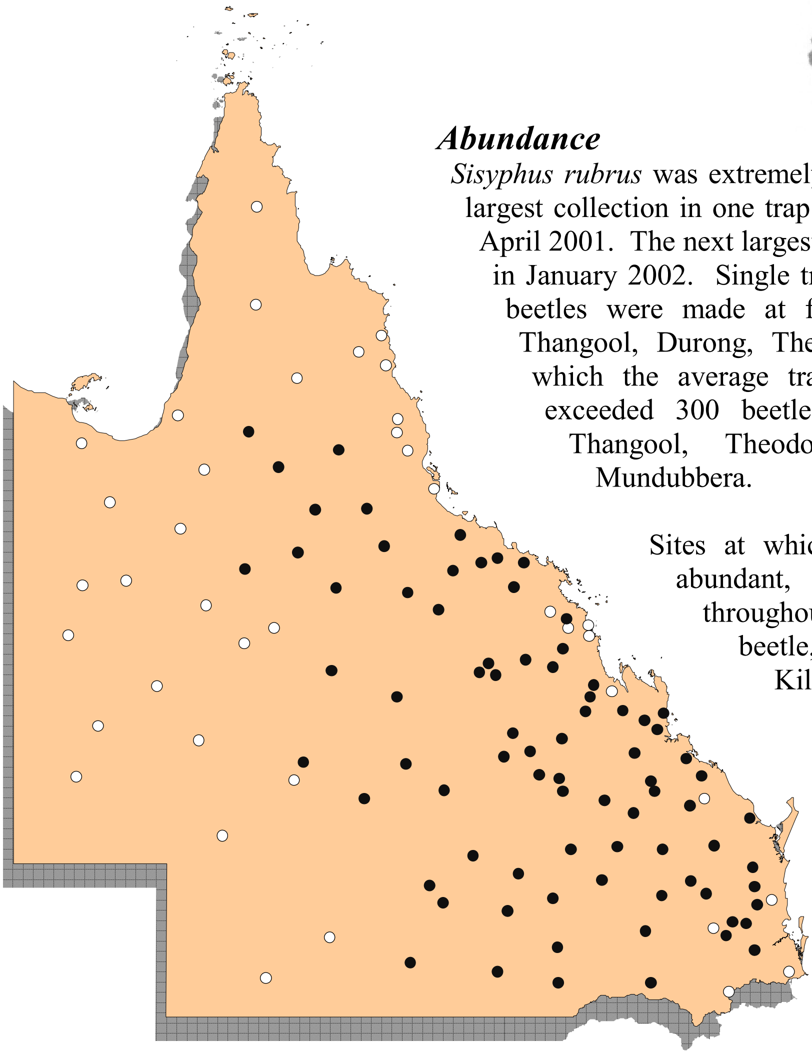
Sisyphus spinipes was most abundant from December to April, with peaks in numbers in December/January and March/April. Numbers were low from May to November. The highest average trap catch of 27 beetles occurred in March 2002.

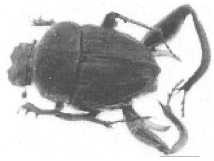


Sisyphus rubrus

Distribution

Sisyphus rubrus was trapped at 80 sites. It extended further west than *Sisyphus spinipes*.





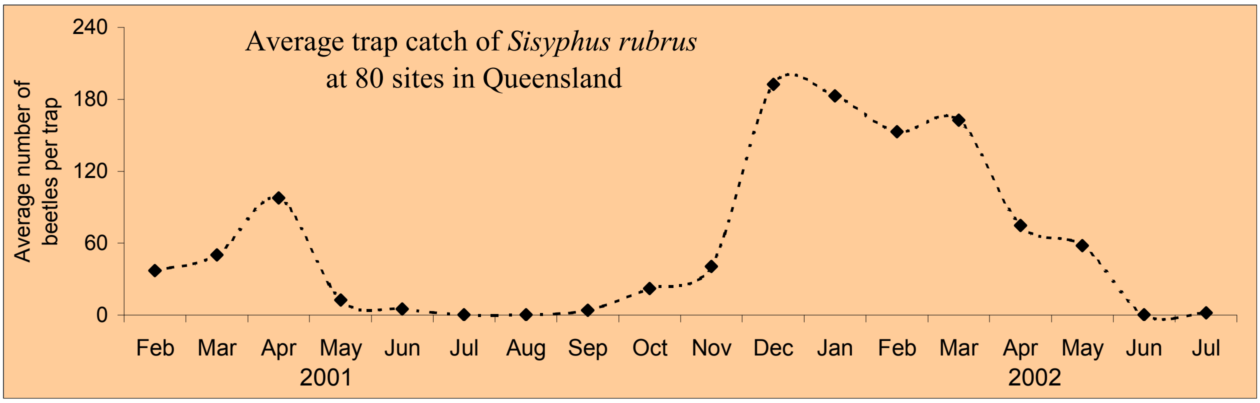
Abundance

Sisyphus rubrus was extremely abundant at many sites. The largest collection in one trap was 4,182 beetles at Moura in April 2001. The next largest catch was 4,055 at Rolleston 2 in January 2002. Single trap catches of more than 2,000 beetles were made at five other sites (Mundubbera, Thangool, Durong, Theodore and Injune). Sites at which the average trap catch throughout the year exceeded 300 beetles were Moura, Rolleston 2, Thangool, Theodore, Durong, Jackson and Mundubbera.

Sites at which *Sisyphus rubrus* was least abundant, with an average trap catch throughout the year of less than one beetle, were Highfields, Gumlu, Kilcoy, Crows Nest, Childers, Cunnamulla, Mackay St Lawrence, Miriam Vale, Richmond 2. and Georgetown 2. Most of these sites are either close to the east coast, or are on the western extremities of the *Sisyphus rubrus* distribution.

Seasonality

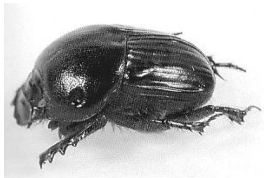
Numbers of *Sisyphus rubrus* were high from December to April, and low from June to September. The pattern of seasonal abundance of *Sisyphus rubrus* was remarkably similar to that of *Sisyphus spinipes*, although numbers of *Sisyphus rubrus* were about eight times higher. The largest average trap catch of 193 beetles occurred in December 2001.

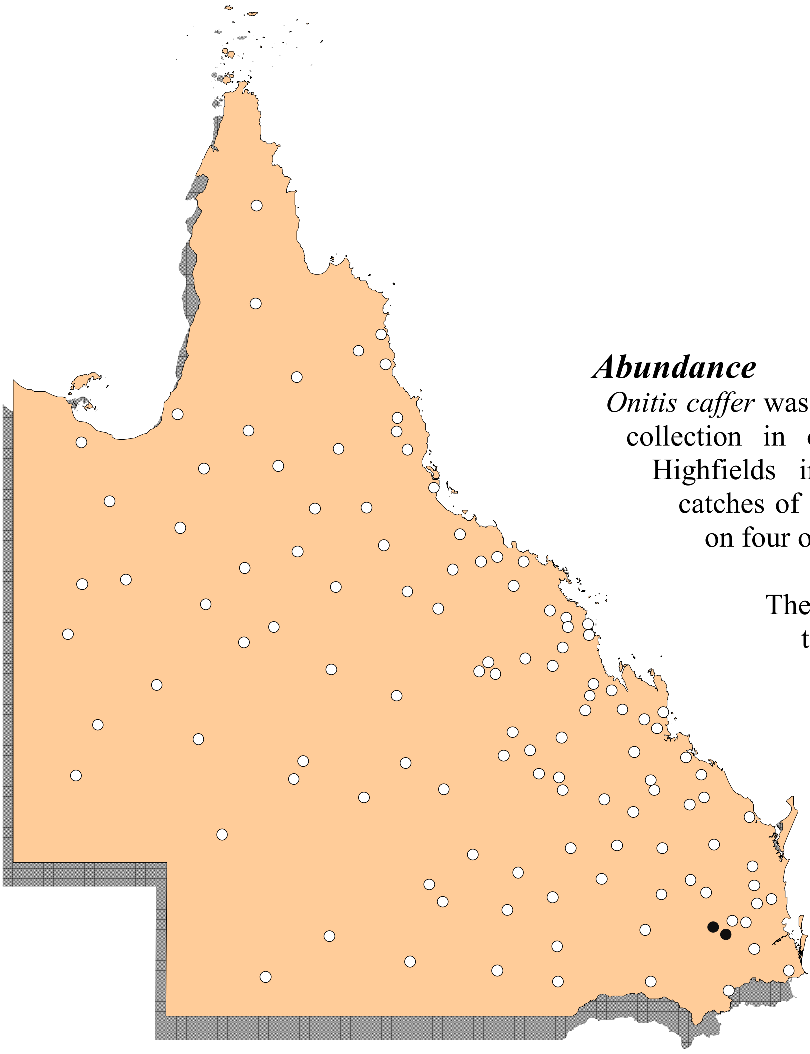


Onitis caffer

Distribution

Onitis caffer was trapped at 2 sites in southeast Queensland. It was found at the Crows Nest site, but was not trapped there. Specimens were also found at Cooyar, 10 km NE of Dalby and 20 km W of Toowoomba.





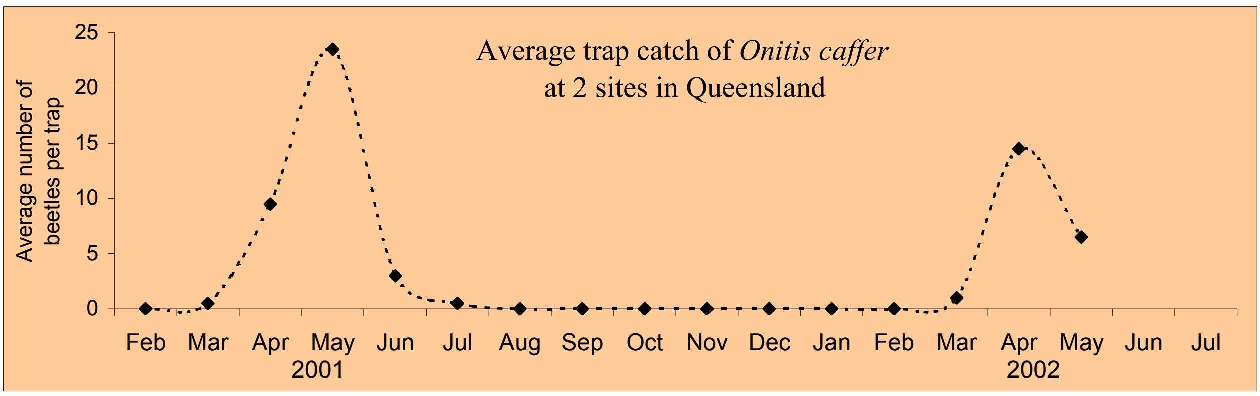
Abundance

Onitis caffer was trapped at 2 sites. The largest collection in one trap was 40 beetles at Highfields in May 2001. Single trap catches of 10 or more beetles were made on four occasions, all at Highfields.

The average trap catch throughout the year was 3.9 beetles at Highfields and 0.2 beetles at Oakey.

Seasonality

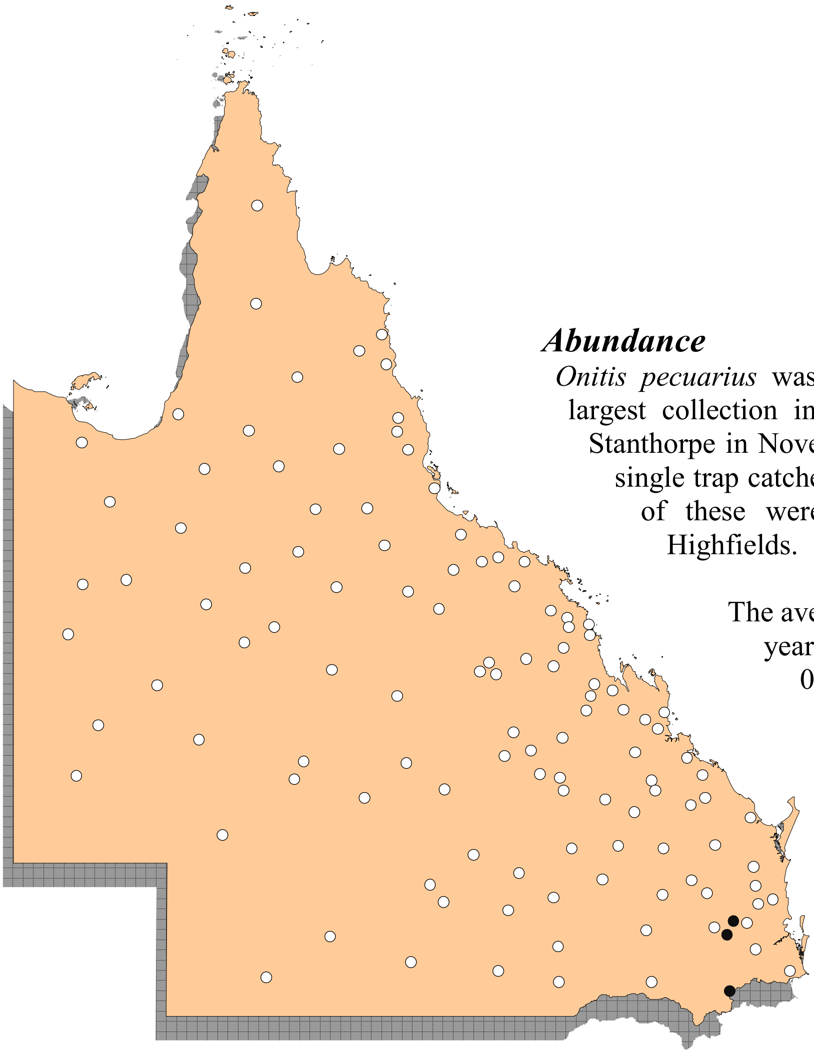
Onitis caffer was abundant between April and June, with the first beetles collected in March each year. No beetles were trapped between August and February. *Onitis caffer* has a single generation per year, and spends the spring and summer as larvae in the soil.

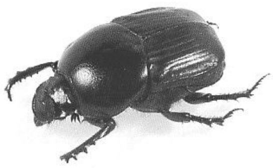


Onitis pecuarius

Distribution

Onitis pecuarius was trapped at 3 sites in southeast Queensland. In addition, a specimen was received from Laidley following a Training Day.





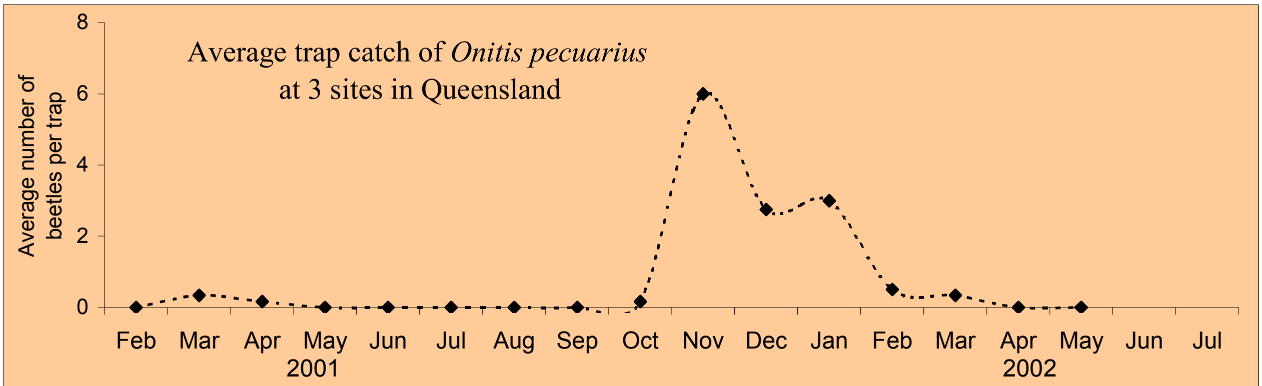
Abundance

Onitis pecuarius was trapped at three sites. The largest collection in one trap was 15 beetles at Stanthorpe in November 2001. There were five single trap catches greater than 5 beetles. Four of these were at Stanthorpe and one at Highfields.

The average trap catch throughout the year was 1.9 beetles at Stanthorpe, 0.4 beetles at Highfields and 0.1 beetles at Crows Nest

Seasonality

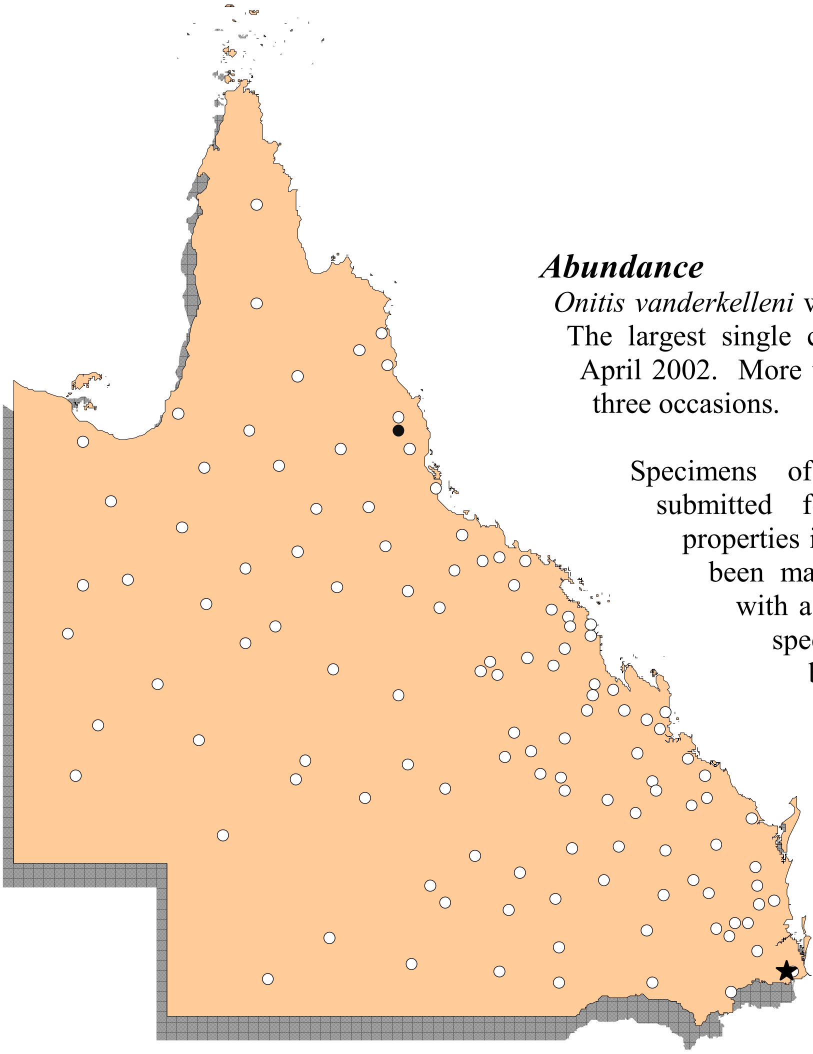
Maximum numbers of *Onitis pecuarius* were recorded in November. There was a smaller peak in January. There was no activity from April to October.

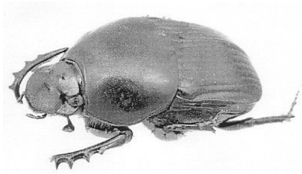


Onitis vanderkelleni

Distribution

Onitis vanderkelleni was trapped at one site in north Queensland. It was recorded from a second site in southeast Queensland by landholders who submitted samples for identification following a Training Day.





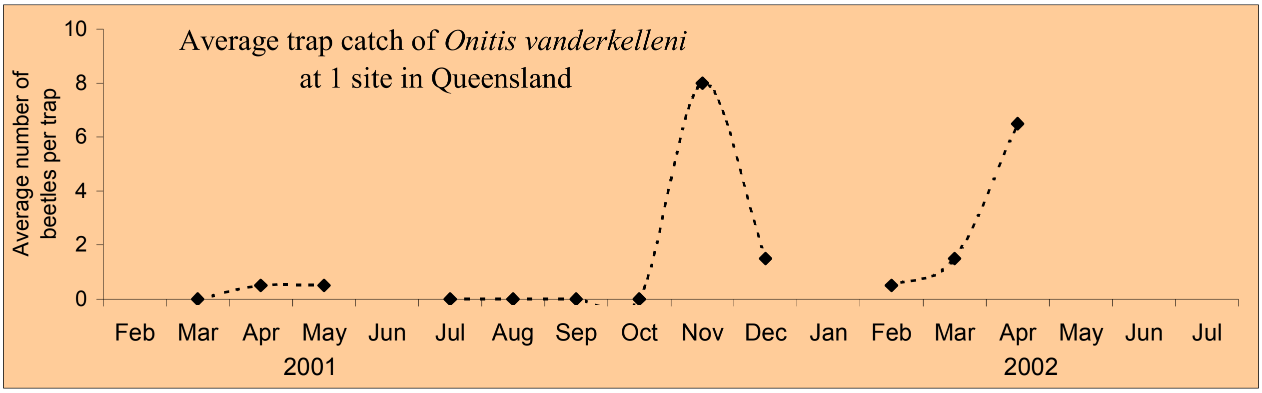
Abundance

Onitis vanderkelleni was trapped only at Ravenshoe. The largest single catch there was 13 beetles in April 2002. More than 5 beetles were trapped on three occasions.

Specimens of *Onits vanderkelleni* were submitted for identification from two properties in Beechmont. Beechmont has been marked on the distribution map with a star. Notes included with the specimens indicated that the beetles were quite abundant at the time of collection (January/February 2002). Ravenshoe and Beechmont are both high altitude sites, with high annual rainfall.

Seasonality

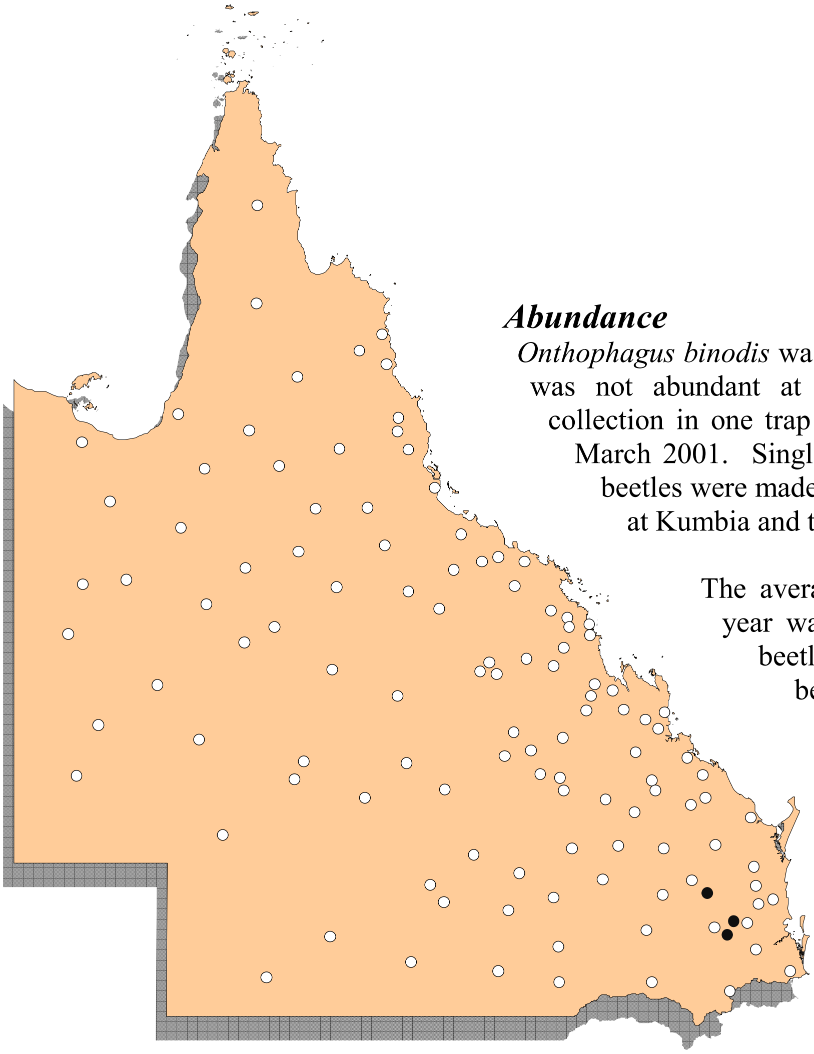
Information on the seasonal activity of *Onitis vanderkelleni* is limited to the data from Ravenshoe. There was a peak in abundance in November, and indications of a second peak in April/May.



Onthophagus binodis

Distribution

Onthophagus binodis was trapped at three sites in southeast Queensland.



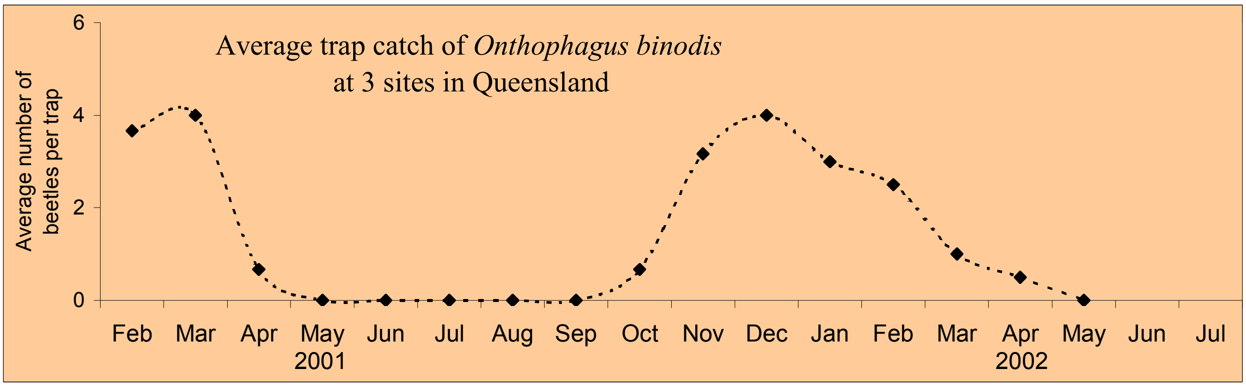
Abundance

Onthophagus binodis was only found at three sites, and was not abundant at any of them. The largest collection in one trap was 14 beetles at Kumbia in March 2001. Single trap catches of more than 5 beetles were made on eight occasions, five times at Kumbia and three times at Highfields.

The average trap catch throughout the year was 2.0 beetles at Kumbia, 1.8 beetles at Highfields and 0.5 beetles at Crows Nest.

Seasonality

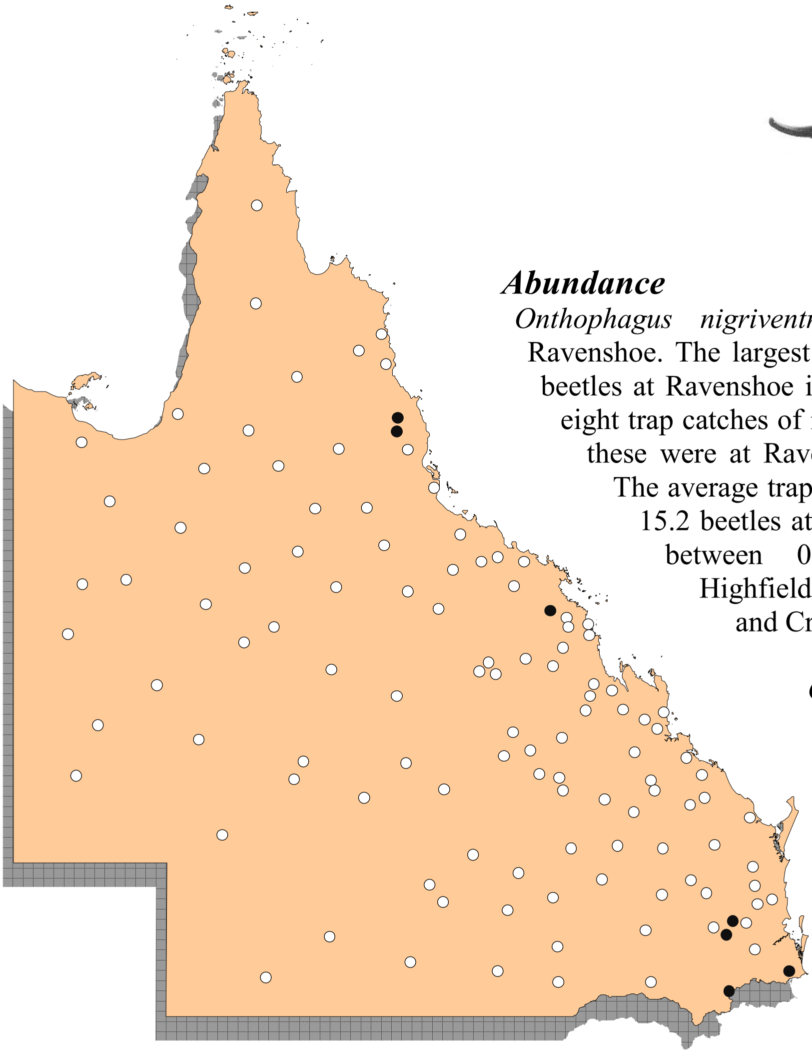
Numbers of *Onthophagus binodis* were highest between November and March. It was not trapped between May and September.

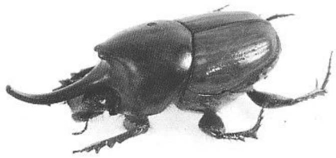


Onthophagus nigriventris

Distribution

Onthophagus nigriventris was trapped at seven sites, mostly sites at high altitude and with high rainfall.





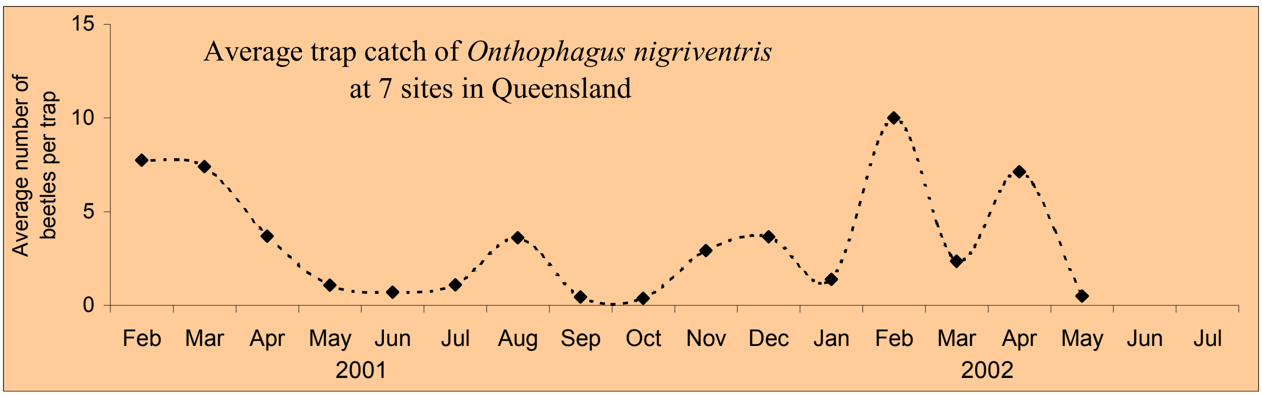
Abundance

Onthophagus nigriventris was most abundant at Ravenshoe. The largest collection in one trap was 65 beetles at Ravenshoe in February 2002. There were eight trap catches of more than 20 beetles. Seven of these were at Ravenshoe and one at Highfields. The average trap catch throughout the year was 15.2 beetles at Ravenshoe. The average was between 0.8 and 2.5 at Malanda, Highfields, Eungella, Numinbah Valley and Crows Nest.

Onthophagus nigriventris was least abundant at Stanthorpe, where only one beetle was trapped. This gave an average trap catch throughout the year of 0.04 beetles for this site.

Seasonality

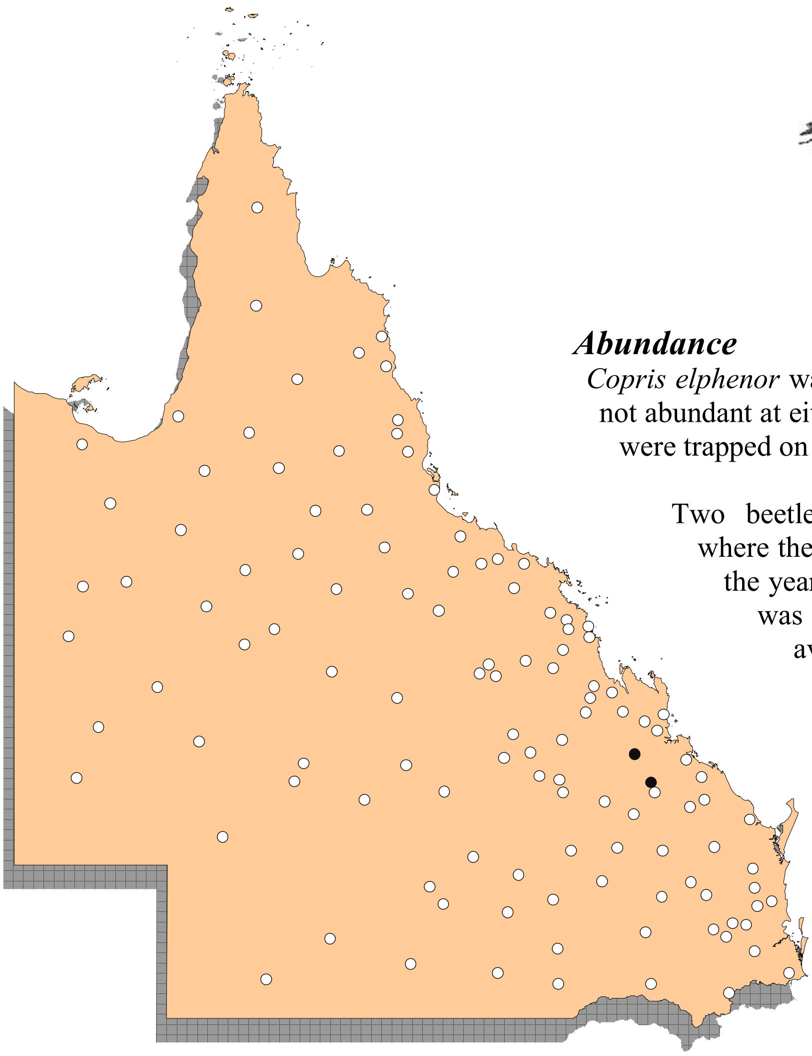
Onthophagus nigriventris was trapped at very few sites, hence the monthly average trap catches are quite variable. Most activity was recorded between November and April. The peak in August 2001 was strongly influenced by a single trap catch of 41 beetles from Ravenshoe.

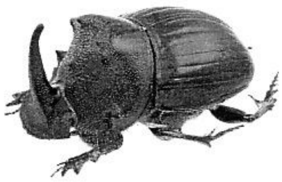


Copris elphenor

Distribution

Copris elphenor was trapped at two sites in central Queensland.





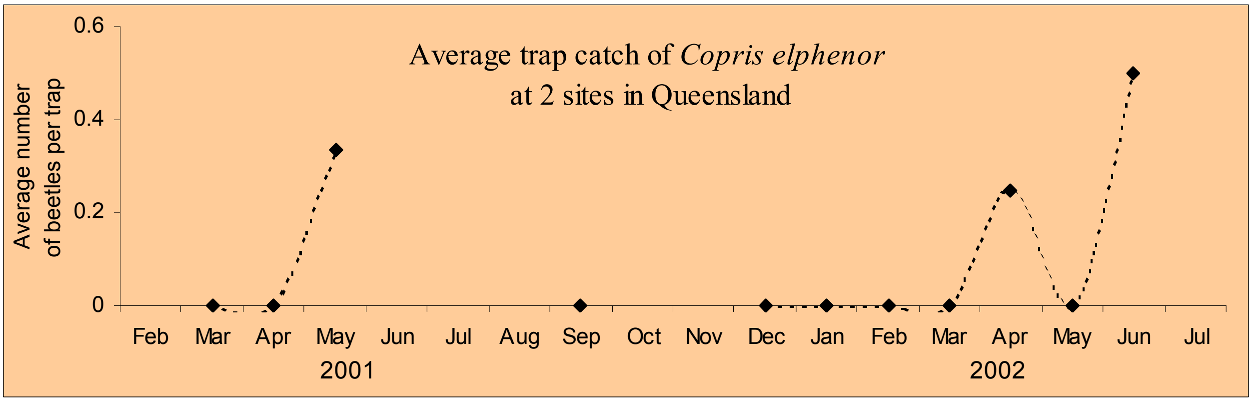
Abundance

Copris elphenor was trapped at two sites. It was not abundant at either site. In total, three beetles were trapped on three separate occasions.

Two beetles were trapped at Wowan, where the average trap catch throughout the year was 0.18 beetles. One beetle was trapped at Biloela, where the average trap catch throughout the year was 0.08 beetles.

Seasonality

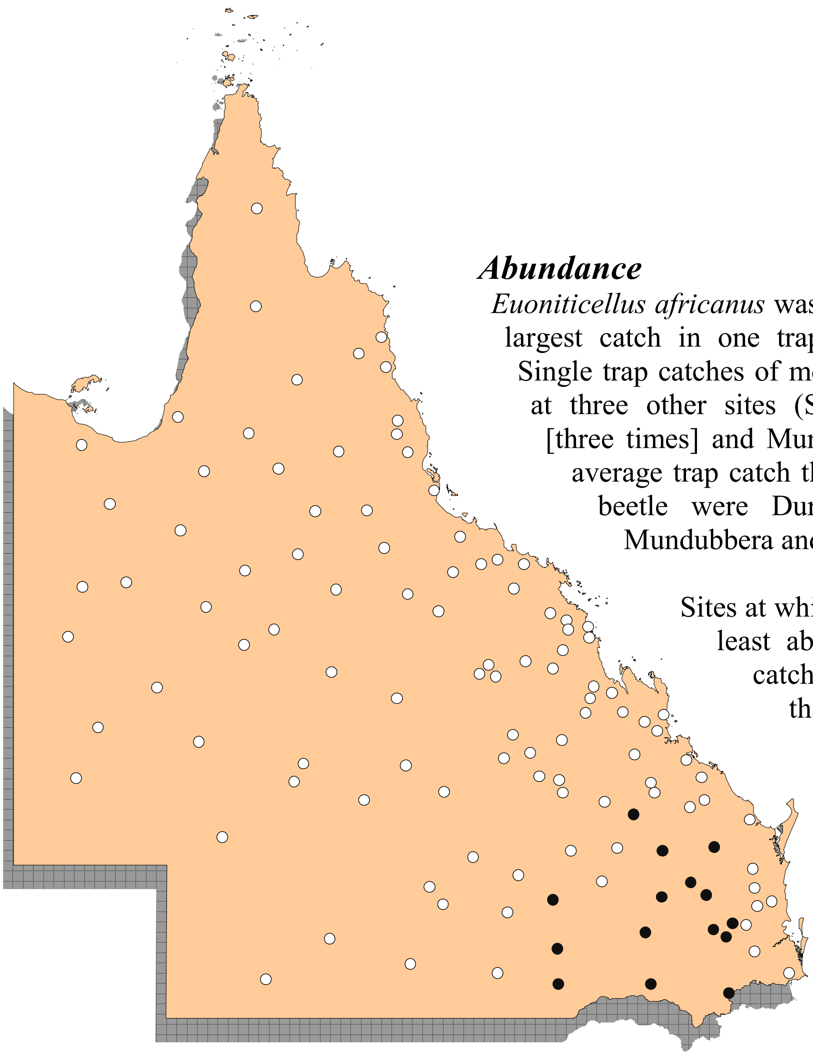
There was insufficient trapping data from the two sites (see graph below) to derive an accurate picture of the seasonal activity of *Copris elphenor*. However field studies during the summer of 2001-02 and 2002-03 near Biloela provided additional information. In both years there was a significant emergence of adult beetles following the first substantial rains in spring (November 2001 and December 2002). Activity continued at a lower level through the summer, particularly after rain. Progeny (i.e. young beetles) of the beetles that emerged in spring appeared from mid-summer onwards.

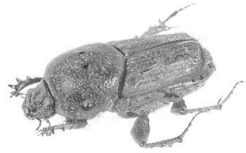


Euoniticellus africanus

Distribution

Euoniticellus africanus was trapped at 15 sites in southeast Queensland.





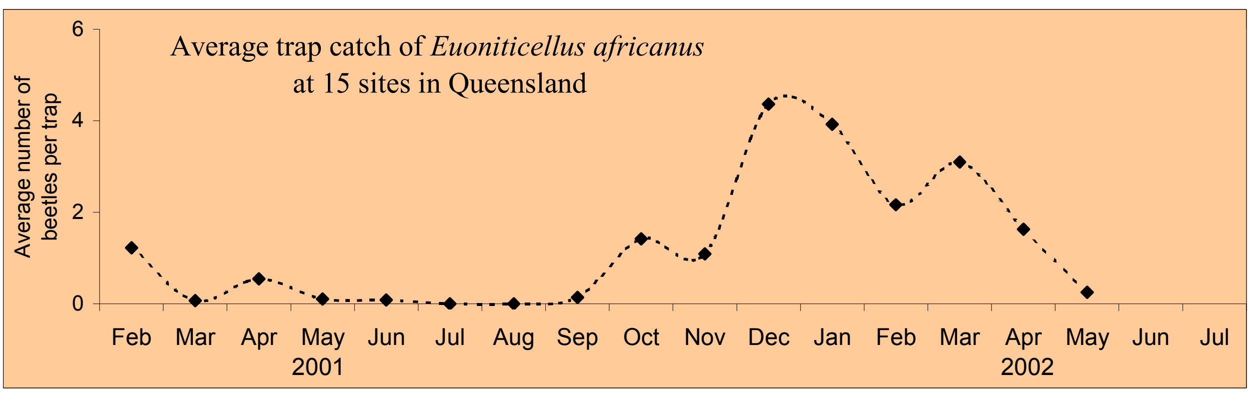
Abundance

Euoniticellus africanus was not abundant at any site. The largest catch in one trap was 68 beetles at Durong. Single trap catches of more than 10 beetles were made at three other sites (Stanthorpe [twice], Highfields [three times] and Mundubbera). Sites at which the average trap catch throughout the year exceeded 1 beetle were Durong, Stanthorpe, Highfields, Mundubbera and Chinchilla.

Sites at which *Euoniticellus africanus* was least abundant, with an average trap catch throughout the year of fewer than 0.1 beetle were St George, Goondiwindi, Theodore, Gayndah and Roma. These last three sites returned only one beetle each.

Seasonality

Euoniticellus africanus was active between October and April, with highest numbers recorded in December/January. There were peaks in abundance in October, December/January and March/April.



ii) Species richness at each site

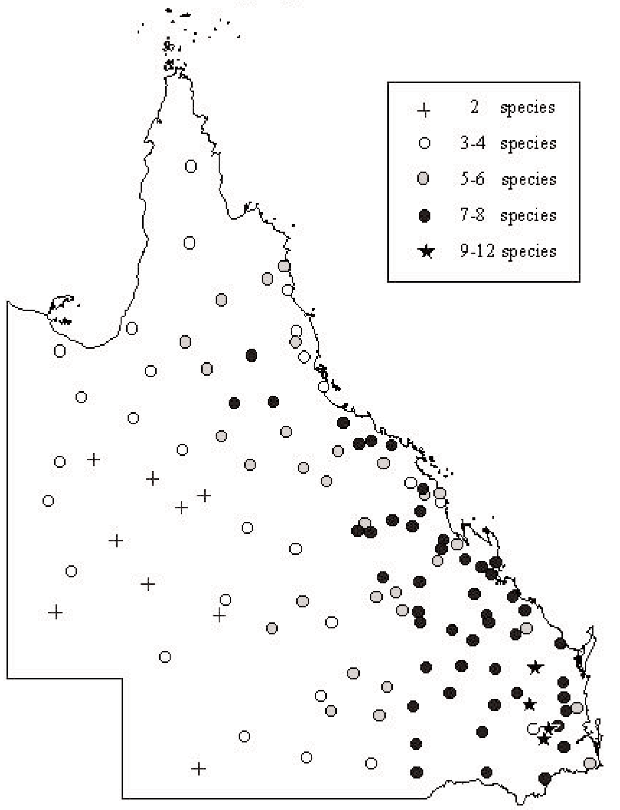
The number of introduced dung beetle species at each site is shown in Figure 10. The number ranged from 2 to 12 species per site. There was an increase in number of species with an increase in the average annual rainfall, but this decreased again in the highest rainfall zones. The highest diversity of species occurred in the 400 – 600 mm zone (see Figure 3a). The number of species declined towards the north, particularly where the average annual maximum temperature exceeded 30^{o}C (see Figure 3b).

It is usually considered desirable to have as many species established at one site as possible. For instance:

- it is desirable to have night (or dusk) flying species as well as day-flying species. This increases the chance that all dung pads will be colonised, whether they are dropped during the day or the night.
- it is desirable to have species with different patterns of seasonal activity. This leads to greater average activity for as long as possible throughout the year.
- a bad year for one species may not be as unfavourable for another species, again resulting in a more steady level of activity
- a mixture of ball-rollers and tunnellers is desirable as in general they take dung from different parts of the dung pad.

Dozens of species can successfully co-exist in one area, and this is frequently seen in Africa, where most of our introduced species originated. Dung beetles have evolved to procure their supply of dung as quickly as possible. They work quickly, and if required, will aggressively defend their piece of dung from competitors.

Figure 10. The number of introduced dung beetle species at each Queensland trapping site



Nonetheless, potential competition is reduced considerably by the spatial and temporal separation of many species. Species may differ in the time of day and the time of year at which they are active, and they also may remove dung in different ways, and to different locations.

Ball rollers remove dung, usually from the surface of the dung pad, and roll it away from the dung pad before burying it. Tunnelers take dung from within the dung pad, and bury it beneath the pad. Dung may be buried at different depths – for instance *Onitis viridulus* buries dung just beneath the dung pad, *Onitis alexis* buries it at about 30 cm at an angle away from the dung pad, and *Onitis caffer* buries dung at 60-100cm, depending on soil type. This results in spatial separation of underground nests, and thus less interference between species.

It is perhaps ironical that the site with the most introduced species, Highfields (near Toowoomba) with 12 species, did not record high beetle catches. The highest number of introduced beetles caught in a trap at Highfields was 265. In contrast, the highest number caught at Blackall 1 was 1,842, where six introduced species occur, and at Hughenden was 2,654, where five species occur.

The high number of species in the Toowoomba region is perhaps due to the fact that the area seems to be an overlap zone for two groups of dung beetles. A more northern, or subtropical fauna is found there (with species such as *Onitis viridulus*, *Sisyphus rubrus* and *Liatongus militaris*), but also a more southern, or temperate, fauna (with species such as *Onthophagus binodis*, *Onitis pecuarius* and *Euoniticellus africanus*). This results in a higher number of species than occurs either further south in NSW or further north in Queensland. Furthermore the region may not be climatically optimal for some of these species, with the more temperate species at their northern limits, and the more subtropical species at their southern limits. The result is that although a large number of species occurs in the region, several of them may not be in a climate where they can flourish.

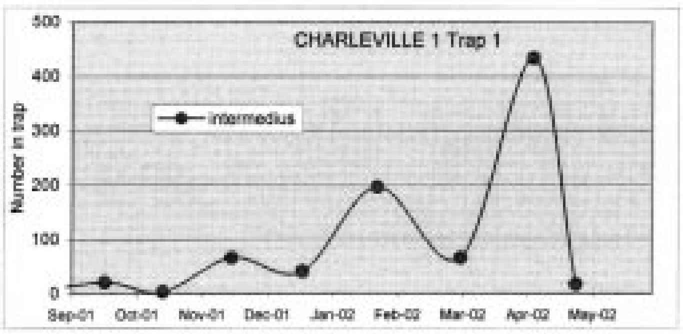
iii) Seasonality of introduced dung beetles

The seasonal patterns of abundance of each species shown with the results in Figure 9 are derived from the average trap catch throughout the state for each month. For many of the more common and widespread species these averages resulted in a smooth curve (e.g. *Onthophagus gazella, Euoniticellus intermedius* and *Liatongus militaris*).

However at individual properties, large fluctuations in numbers of each species occurred between months. An example is shown in Figure 11 of *Euoniticellus intermedius* at Charleville 1. Three distinct peaks in numbers of beetles trapped were observed during the 2001-2002 summer season. A peak in the number of beetles often corresponds to the emergences of a new generation of beetles.

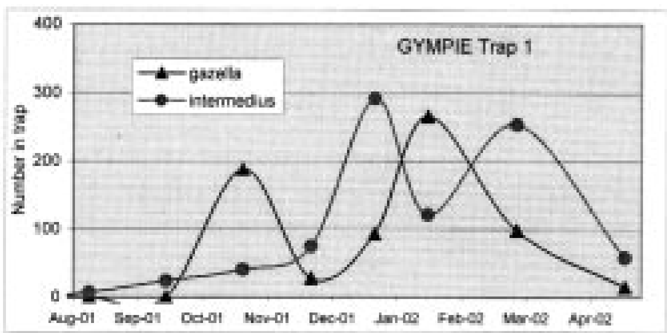
For most introduced species, there was evidence of two to three generations during the season of activity (spring to autumn) at most sites around Queensland. The generation length of most introduced species is approximately two months, which is consistent with the observed pattern of peaks in numbers approximately every two months.

Figure 11. Numbers of *Euoniticellus intermedius* caught in Trap 1 at Charleville 1.



A more constant level of dung beetle activity results when several introduced species coexist in an area. This is particularly the case if the peaks in abundance of different species are not synchronous. Results from Gympie (Figure 12) provide an example where the peaks in numbers of two species occurred in different months. This produced a steadier level of dung beetle activity than if the peaks of the two species had occurred in the same months.

Figure 12. Numbers of *Onthophagus gazella* and *Euoniticellus intermedius* caught in Trap 1 at Gympie.



The rainfall data presented in Figure 4 showed that, for many parts of the state, rainfall was below average during the period of the survey. It is difficult to quantify what affect this had on the seasonal abundance of dung beetles. It was frequently noted that activity increased after rainfall. However the general pattern of peaks and troughs in numbers of each species was observed at most sites, regardless of whether the rainfall was above or below average. It is likely that, for many species, the first emergence in spring is triggered by a combination of soil temperature and rainfall. Thereafter population events will largely take their own course, modified to a certain extent by the prevailing conditions of rainfall and temperature.

Rainfall can also impact on the survival of dung beetles via its effect on soil moisture. Extremely dry soil can accelerate the desiccation of the dung on which larvae are feeding, resulting in increased mortality of larvae and emergence of smaller sized adults. Wet and waterlogged soil can also result in high mortality of larvae.
Thus rainfall can have a short term and a long term effect on dung beetle population numbers and activity. To separate out the various effects would require a long term study over several years. The data from this survey can be used to compare with any future studies.

iv) Introduced species that were not found during the 2001-2002 survey

Of the 29 species of dung beetles introduced into Queensland from the late 1960s to early 1980s, 14 were not collected in the 2001-2002 survey.

Eleven species that were released in Queensland have never been recovered. These are *Allogymnopleurus thalassinus, Copris bornemisszae, Copris incertus, Copris diversus, Onitis crenatus, Onitis deceptor, Onitis uncinatus, Onitis westermanni, Onthophagus foliaceus, Sisyphus fortuitus and Sisyphus mirabilis.* Some of these were released in very small numbers and so their non-establishment is not surprising. However several thousands were released of some species, and their non-establishment is a disappointing result from the original CSIRO project. These species include *Copris diversus* and *Onitis westermanni.*

Three species were found after their original introduction, but were not collected during this project. The most significant of these is *Onthophagus obliquus*. It was released at six sites in northern Queensland in 1976 and 1977. It was subsequently recovered at Cooktown in 1980, and has been recorded there in good numbers in more recent times (J. Feehan, personal communication). During this project it was not trapped at the Cooktown site, although traps were only set there on three occasions. Staff visited Cooktown several times during the project, and *Onthophagus obliquus* was not found. However it is to be hoped that the species does still exist in the area, and in sufficient numbers that redistributions may be possible in the future.

2,000 *Copris fallaciosus* were released at Westwood in 1977 and 1978. A single recovery was made one year later, but no beetles have been found since. Time did not permit a survey to be made at Westwood during the current project.

300 *Sisyphus infuscatus* were released at Jambin in 1976, and it was recovered there in February 1982. It was not collected during the current project.

v) Comments on some introduced species collected in the 2001-2002 survey

Euoniticellus africanus was released in Queensland in the mid 1970s at Rockhampton, Mossman and Atherton. In the current survey it was not collected in these areas, but only in the inland south-eastern area of the state (see figure 9o). The most northerly and north-westerly collection sites were Roma, Theodore and Gayndah, with only one beetle caught at each. The largest collections came from nearer the NSW border. *Euoniticellus africanus* was released at several sites in northern NSW, including Tenterfield and Moree, in the mid 1970s. It is thus probable that the current distribution in southern Queensland is a result of natural dispersal from northern NSW. If this is the case, then it has spread about 500 km in just under 30 years. In South Africa, it does not occur as far north as does *Euoniticellus intermedius*, and it is probable that it will not spread much further into Queensland.

The opinion was frequently expressed by landholders during the trapping program that the numbers of ***Onitis alexis*** and ***Onitis viridulus*** caught in the traps was far lower than expected, based on the level of activity of these species seen at the time of trapping. A couple of preliminary trials conducted by project staff, comparing catches in pitfall traps with catches made in dung pads placed on plastic sheeting, supported this suggestion. (Plastic sheets were used so that beetles were attracted to the dung pad, but could not bury the dung. The beetles could be collected easily from the dung on the plastic in the morning). The evidence was that more of these two species were collected in the dung pads on plastic sheeting than in pitfall traps in the same area. Furthermore, the distribution of the beetles in the pads on plastic was quite clumped. For instance, there may have been several *Onitis alexis* in one pad, several *Onitis viridulus* in another pad, and maybe no beetles in another pad. This indicated that beetles of the same species might have been attracted to each other. It is possible that *Onitis* beetles caught in a pitfall trap did not attract members of the same species, in the way that beetles in dung pads did. Further trials would be required to test this hypothesis more thoroughly.

It was often noted by landholders that some dung pads appeared more attractive to ***Sisyphus*** beetles than did others. It is possible that the churning activity of beetles prevented the dung crusting over, making it more attractive to additional beetles. On the other hand, dung pads where there was less initial activity would crust over and rapidly lose their attractiveness, resulting in a very asymmetrical distribution of beetles in pads of the same age. It is not known how this phenomenon was reflected in trap catches. It is assumed that trap baits would be less attractive than a dung pad churned by beetles, but possibly more attractive than a crusted dug pad. Thus the catch in a pitfall trap might provide a reasonable estimate of the average level of activity in an area.

vi) Average abundance of introduced dung beetles

A useful measure of overall beetle activity at a site is the average trap catch for the whole year. Table 2 presents the average trap catch of introduced beetles for the entire season, for the 72 sites where 18 or more samples were collected (that is 2 traps set for 9 months). This was to ensure that sampling had been done in most months of the year, to enable valid comparisons to be made between sites. The highest average trap catch was 1,098 beetles at Thangool. The top ten sites, all with an average trap catch of more than 500 beetles were Thangool, Rolleston 1, Woodstock, Durong, Jackson, Theodore, Injune, Childers, Ayr and Mundubbera. These sites all had 7 or 8 species present.

The lowest average trap catch of introduced species was 5 beetles at Numinbah Valley. The bottom ten sites, with an average trap catch of fewer than 48 beetles, were Numinbah Valley, Malanda, Ravenshoe, Aramac, Maleny, Daintree, Richmond 1, Stanthorpe, Tully and Kumbia. These sites had between 2 and 9 introduced species.

The three sites with the highest number of species (Highfields [12 species], Crows Nest [11 species] and Kumbia [9 species]) are all in the bottom part of Table 2, and all have species from both the 'northern ' subtropical group and the 'southern' temperate group.

The figures in Table 2 demonstrate that there is a huge disparity between 'good' dung beetle areas and 'poor' dung beetle areas. Most of the 'good' dung beetle sites were where the annual rainfall is between 600 and 800 mm (Childers is a notable exception) and the annual average maximum temperature is between 27^{o}C and 30^{o}C. Most of the 'poor' sites were where the annual rainfall is greater than 1,200 mm or below 450 mm, or the annual average maximum temperature is below 24^{o}C.

The 'poor' dung beetle areas are only 'poor' in terms of the currently available dung beetle species. To improve dung beetle activity in these regions, additional introduced species would be required. In particular, species adapted to low rainfall (below 500 mm per year) or high rainfall (above 1,200 mm per year) would be required.

Table 2. Average number of introduced beetles caught per trap at each site. (Only sites where at least 18 samples were collected are included.)

Locality	Average number of beetles per trap catch	Number of introduced species
Thangool	1098	7
Rolleston1	1001	7
Woodstock	751	8
Durong	661	8
Jackson	660	7
Theodore	646	8
Injune	618	7
Childers	616	8
Ayr	609	8
Mundubbera	562	8
Rockhampton 2	459	8
Sapphire	456	7
Gayndah	447	9
Blackall 1	373	6
Richmond 3	346	5
Kilcoy	318	8
Clermont 3	316	7
Chillagoe	306	5
St George	302	7
Charters Towers 2	296	6
Monto	268	7
Goondiwindi	256	7
Moranbah	256	7
Marlborough 2	255	7
Charleville 2	252	5
Rosewood	248	7
Julia Creek 1	238	3
Hughenden	227	5
Bowen	226	7
Emerald	224	6
Einasleigh	223	7
Roma	216	7
Lakeland	213	6
Collinsville	212	6
Chinchilla	202	8
Nebo 2	198	7
Gumlu	191	7
Mackay	176	7
Clermont 1	169	7
Nindigully	167	7
Clermont 2	166	6
Rockhampton 1	165	8
Marlborough 1	158	7
Gympie	132	8
Esk	128	8
Normanton	128	3
Miriam Vale	126	8
Charleville 1	124	4
Mitchell 1	113	6
Mount Surprise	110	7
Taroom	109	7
Tara	102	7
Julia Creek 2	99	2
Burketown 2	96	3
Richmond 2	89	4
Quilpie	78	3
Musgrave	76	4
Highfields	72	12
Georgetown 1	69	5
Crows Nest	61	11
Imbil	52	8
St Lawrence	48	8
Kumbia	47	9
Tully	45	4
Stanthorpe	30	7
Richmond 1	26	2
Daintree	25	4
Maleny	22	6
Aramac	21	4
Ravenshoe	18	5
Malanda	6	4
Numinbah Valley	5	6

4. NATIVE DUNG BEETLES

Following his visit to Australia in 1836, Charles Darwin wrote:

"In Van Diemen's Land …. I found four species of Onthophagus, two of Aphodius, and one of a third genus, very abundantly under the dung of cows; yet these latter animals had been then introduced only thirty-three years. Previous to that time the kangaroo and some other small animals were the only quadrupeds; and their dung is of a very different quality from that of their successors introduced by man …… The change, therefore, in habits which must have taken place in Van Diemen's Land is highly remarkable."

i) Species of native dung beetles collected during the 2001-2002 survey

If he had returned to Australia in 2002, Charles Darwin would have found the changes in habits of the native dung beetles in Queensland even more remarkable than those he saw in Van Diemen's Land in 1836. (He may also have wondered how all those African dung beetles had reached our shores). Seventy-three species of native dung beetles were collected during the trapping program. This was considerably more than was anticipated at the start of the project.

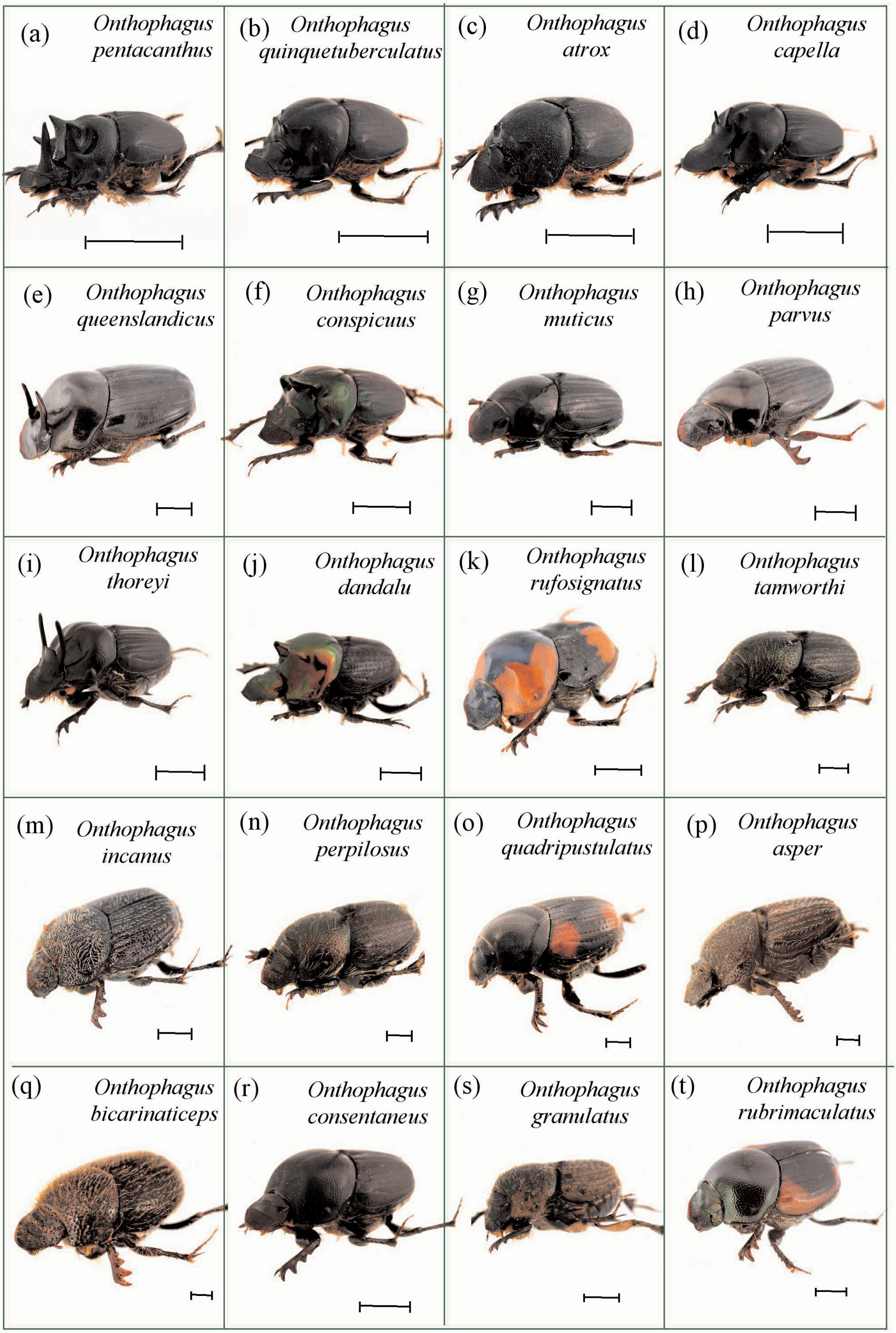
Approximately 350-400 species of native dung beetles are known to occur in Australia. While some feed on rotting mushrooms and decaying animal carcases, the majority have evolved to feed on the dry pelleted dung of marsupials, just as Darwin surmised. It was thus surprising to record the large number of these species that are now attracted to the large moist dung pads of cattle. While it cannot be stated conclusively that beetles attracted to cattle dung will feed and breed in it, it is reasonable to assume that the vast majority will. It would be interesting to know to what extent native species that are now utilising cattle dung are also still using marsupial dung.

A list of all the 73 native dung beetle species collected during the project is presented in Table 3. Fifty-nine (or 81%) of the species collected during this study belong to the genus *Onthophagus*, which is a cosmopolitan genus. The species are grouped in Table 3 according to taxonomic similarity (based on Matthews 1972), with the *Onthophagus* species listed first.

The size of each species of native dung beetle (large, medium, small, very small) is included in Table 3. The groups of *Onthophagu*s species (Groups A to N) are presented in descending order of size (Group A being the largest). The body length of each species is given (from Matthews 1972 and R. Storey). As a comparison with the introduced species, both the common *Onitis* species (*Onitis alexi*s and *Onitis viridulus*) are included in the "large" group. The other introduced species are included in the "medium" and "small" group, except for *Copris elphenor* which is "very large". Many of the native dung beetle species are considerably smaller than any of the introduced species. Some of the tiniest species, such as *O. rubescens*, *O. yeyeko* and *O. minisculus* are not much bigger than a pinhead.

Twenty of the more widespread or distinctive dung beetle species found in cattle dung are shown in Figure 13 (a) - (t).

Figure 13. Twenty native dung beetle species collected from cattle dung.



|—| = approximate body length

Table 3. Native dung beetles collected during the Queensland Dung Beetle Project

	Number of sites where species was found	Number of samples in which species was found	Size of beetles	Range in body length of beetles (mm)
SPECIES GROUP A				
Onthophagus laminatus	7	19	Large	11-22
Onthophagus pentacanthus	10	44	Large	14-20
Onthophagus quinquetuberculatus	17	70	Large	15-19
Onthophagus atrox	40	218	Large	12-19
Onthophagus pugnacior	13	65	Large	12-18
Onthophagus mjobergi	9	18	Large	13-17
Onthophagus capitosus	2	12	Large	10-16
SPECIES GROUP B				
Onthophagus capella	8	65	Large	10-17
Onthophagus tabellicornis	2	2	Medium	10-11
Onthophagus queenslandicus	10	36	Small	6-8
SPECIES GROUP C				
Onthophagus jalamari	1	5	Medium	10-15
Onthophagus tenebrosus	1	3	Medium	9-13
Onthophagus fissiceps	1	1	Medium	10-12
Onthophagus conspicuus	11	26	Medium	8-12
Onthophagus worooa	8	27	Medium	8.2-11.7
Onthophagus mongana	1	3	Medium	8.8-11.1
Onthophagus bicavicollis	1	3	Medium	8-11
SPECIES GROUP D				
Onthophagus glabratus	22	48	Medium	7-12
Onthophagus peramelinus	4	4	Medium	8-11
Onthophagus chepara	7	12	Medium	6.5-10
Onthophagus muticus	38	155	Small	6-9
Onthophagus parvus	31	161	Small	5.5-9
SPECIES GROUP E				
Onthophagus australis	11	56	Medium	7-12
Onthophagus thoreyi	12	60	Medium	8-11
SPECIES GROUP F				
Onthophagus auritis	3	5	Medium	6-11
Onthophagus cuniculus	4	4	Medium	6-10
Onthophagus dandalu	26	94	Small	6-9
Onthophagus rufosignatus	2	2	Small	6-9
SPECIES GROUP G				
Onthophagus arkoola	8	19	Small	5.7-7.2
Onthophagus tamworthi	27	127	Small	6-7
Onthophagus fletcheri	2	11	Small	6-7
Onthophagus gangalu	19	86	Small	5-7
Onthophagus incanus	45	163	Small	4-7
Onthophagus sp. nov. 1 **	5	11	Small	4.0-6.2
Onthophagus wakelbura	15	63	Small	5-6
Onthophagus perpilosus	17	141	Small	4-6
SPECIES GROUP H				
Onthophagus kokeraka	13	34	Very small	3.5-5
Onthophagus waterhousei	1	1	Very small	3-5
Onthophagus quadripustulatus	53	244	Very small	3.5-4.5
Onthophagus cruciger	26	102	Very small	3.5-4
Onthophagus miniscsulus	1	3	Very small	3.5-4.5
SPECIES GROUP I				
Onthophagus manya	4	5	Very small	3.6-4.2
Onthophagus rubescens	2	3	Very small	2.3-3.2

	Number of sites where species was found	Number of samples in which species was found	Size of beetles	Range in body length of beetles (mm)
SPECIES GROUP J				
Onthophagus asper	31	172	Very small	3.5-5
Onthophagus oceliger	10	70	Very small	3-4.5
SPECIES GROUP K				
Onthophagus bicarinaticeps	22	134	Very small	2.5-4.5
Onthophagus yeyeko	7	23	Very small	2.5-3.5
SPECIES GROUP L				
Onthophagus planicollis	2	9	Small	8-9
Onthophagus clypealis	2	4	Small	6-8
SPECIES GROUP M				
Onthophagus yaran	4	17	Small	5.5-8.0
Onthophagus sp. nov. 2 **	1	11	Small	3.8-5.9
Onthophagus sp. nov. 3 *	1	1	Very small	3.8-4.1
SPECIES GROUP N (ungrouped *Onthophagus* species)				
Onthophagus desectus	3	3	Medium	11-15
Onthophagus leanus	5	8	Medium	10-12
Onthophagus consentaneus	69	367	Medium	6-11
Onthophagus granulatus	10	73	Small	6-8
Onthophagus bunamin	1	1	Small	5-7.5
Onthophagus incornutus	12	47	Small	4-7
Onthophagus rubrimaculatus	34	252	Small	4-7
SPECIES GROUP O				
Coptodactyla. onitoides	1	3	Medium	9-13
Coptodactyla meridionalis	1	2	Medium	10-13
Coptodactyla glabricollis	1	5	Large	11-17
Coptodactyla monstrosa	2	8	Medium	11-15
SPECIES GROUP P (ungrouped genera)				
Amphistomus pygmaeus	1	1	Small	4.0-5.0
Lepanus pygmaeus	1	1	Very small	2.1-3.0
Tesserodon novaehollandiae	1	1	Small	3.8-6.1
Monoplistes occidentalis	13	25	Small	4.0-5.5
SPECIES GROUP Q				
Demarziella imitatrix	9	22	Very small	3.1-4.0
Demarziella geminata	5	11	Very small	3.1-4.2
Demarziella yorkensis	3	9	Very small	3.0-5.0
Demarziella mirifica	6	27	Very small	2.9-3.8
Demarziella interrupta	7	15	Very small	3.5-4.1
Demarziella pratensis	6	13	Very small	2.9-3.8

* = undescribed species ** = undescribed species and previously unknown

ii) Two new species of native dung beetles discovered

Three undescribed species were trapped, two of which had never been collected before. This was an exciting outcome for the project. The two newly discovered species will be named and described by Ross Storey.

Onthophagus sp. nov. 1 [Group G] was collected from north of Normanton to north-west of Cloncurry to south-west of Julia Creek. This was one of the newly discovered species.

Onthophagus sp. nov. 2 [Group M] was only collected from the Hughenden site. This was the other newly discovered species.

Onthophagus sp. nov. 3 [Group M] was only collected at the Moranbah site. It has been collected before in this region, usually from brigalow country.

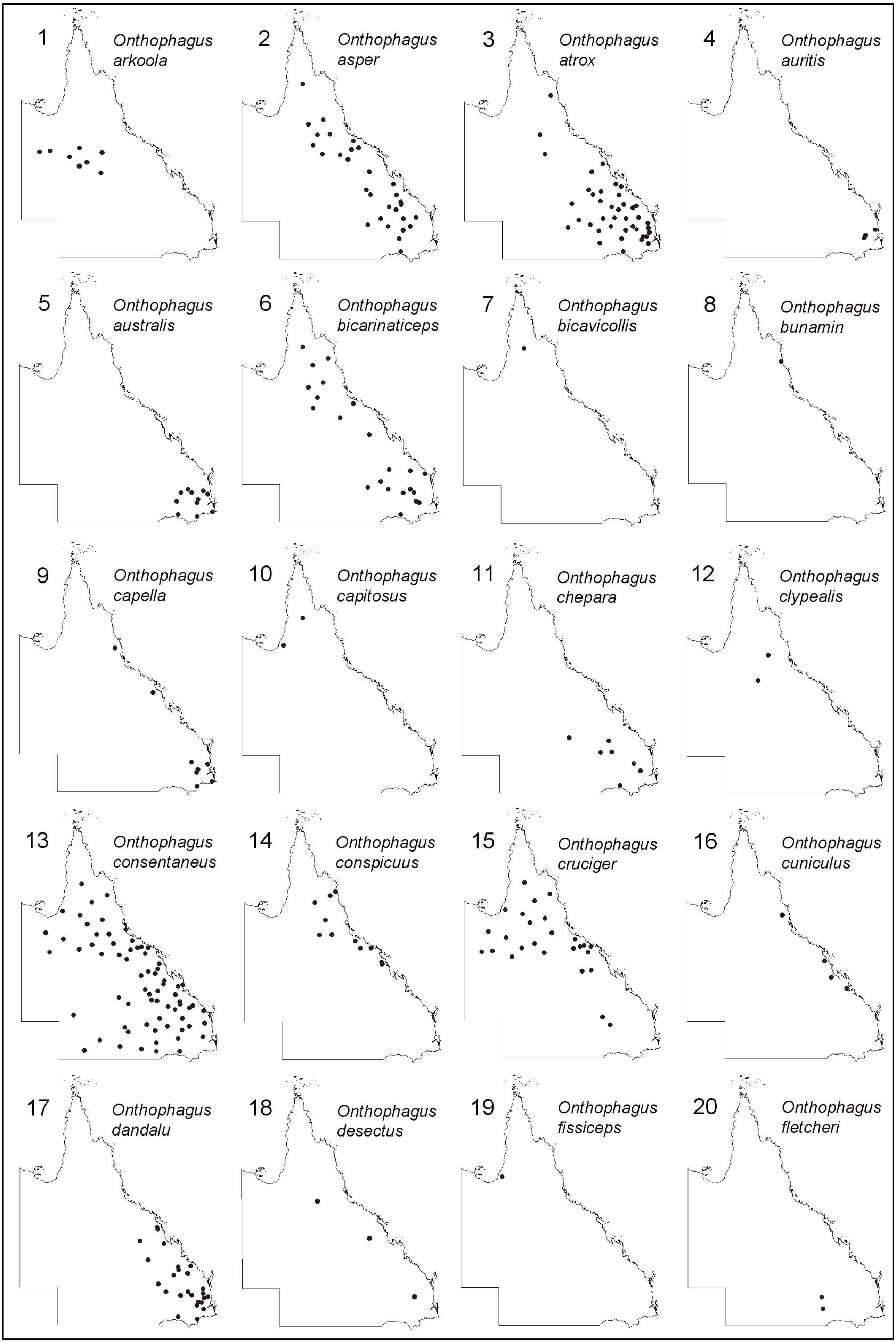
iii) Distribution of native dung beetles

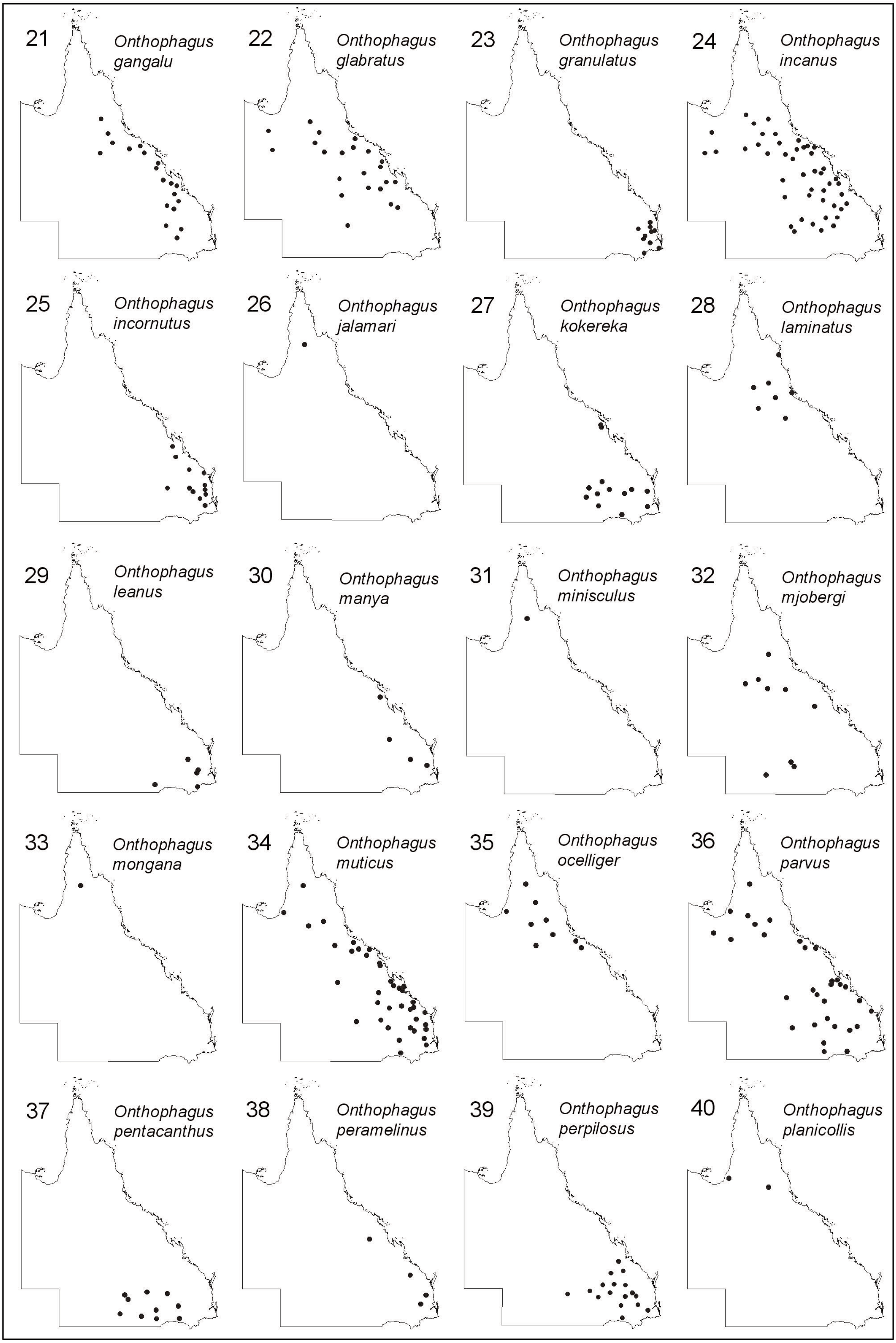
The sites at which each species of native dung beetle were trapped are presented in Figure 14 (maps 1 to 73). The *Onthophagus* species are presented first (Maps 1 to 59), with the species presented alphabetically to make them easier to locate. The *Coptodactyl*a species follow, then the *Demarziella* species, then the remaining four species.

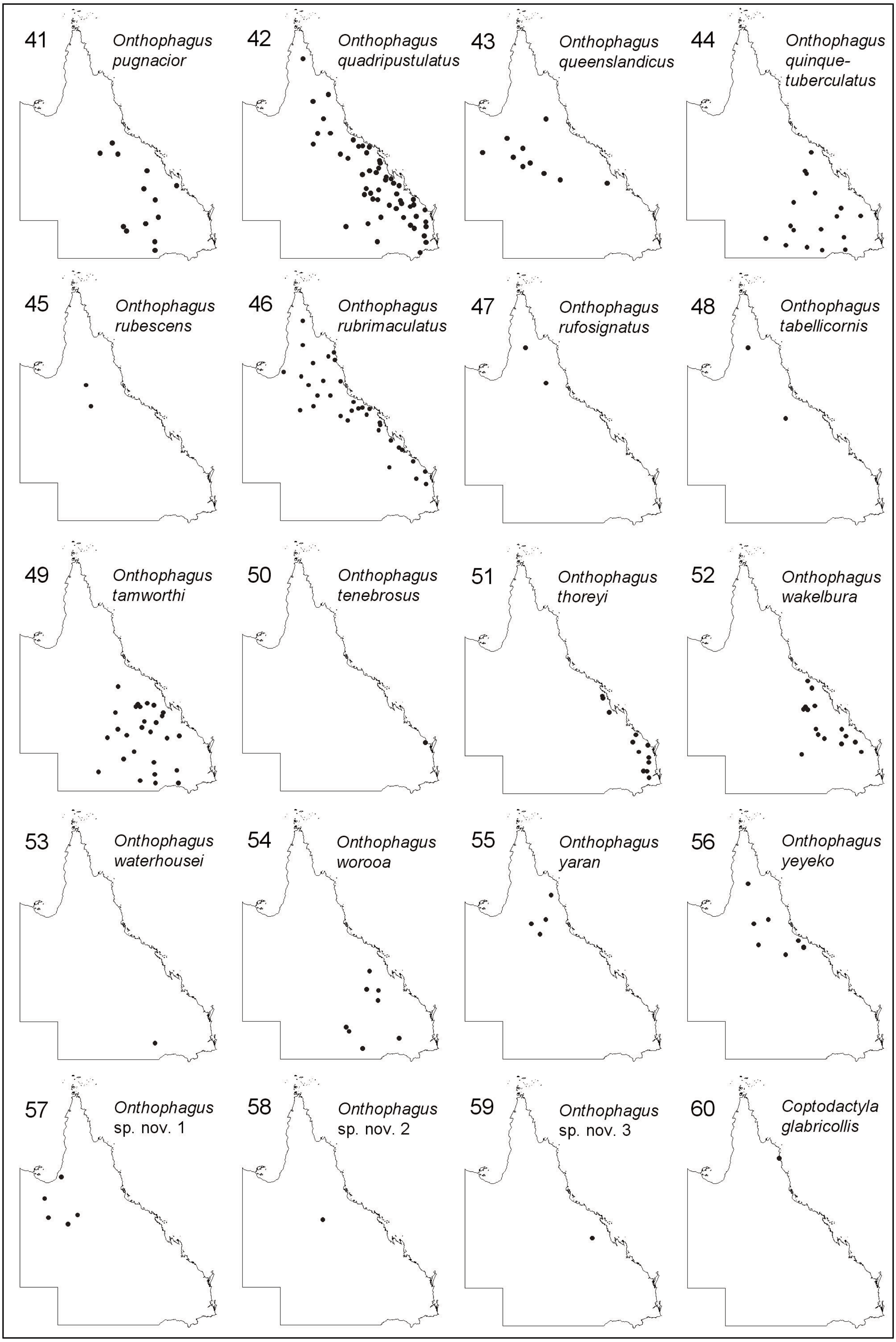
Table 3 includes the number of sites at which each species was found. The most widespread species was *Onthophagus consentaneus*, which was found at 69 sites. The next most widespread was *Onthophagus quadripustulatus* which was found at 53 sites. At the other extreme, sixteen species were each collected at only one site.

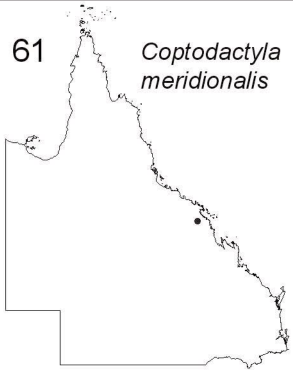
Table 3 also indicates the number of samples in which each species was found. This provides some indication of the abundance (either numerically or seasonally) of each species. For instance *O. tabellicornis* was found in two samples and at two sites. In other words it was found in only one sample from each site, and was thus rare. In contrast *O. capitosus* was also found at two sites, but was returned in 12 samples. It was thus trapped in several months at one or both sites, and was thus relatively common at those sites.

Figure 14. Distribution of native dung beetle species collected during the Queensland Dung Beetle Project 2001-2002

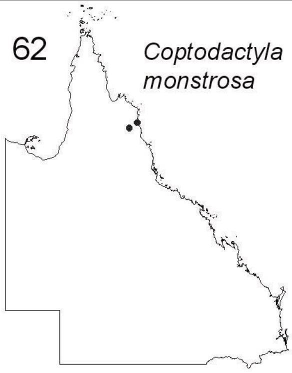



21 Onthophagus gangalu
22 Onthophagus glabratus
23 Onthophagus granulatus
24 Onthophagus incanus
25 Onthophagus incornutus
26 Onthophagus jalamari
27 Onthophagus kokereka
28 Onthophagus laminatus
29 Onthophagus leanus
30 Onthophagus manya
31 Onthophagus minisculus
32 Onthophagus mjobergi
33 Onthophagus mongana
34 Onthophagus muticus
35 Onthophagus ocelliger
36 Onthophagus parvus
37 Onthophagus pentacanthus
38 Onthophagus peramelinus
39 Onthophagus perpilosus
40 Onthophagus planicollis

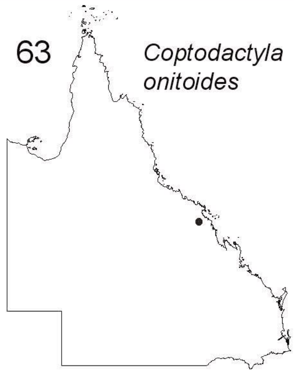

41 *Onthophagus pugnacior*
42 *Onthophagus quadripustulatus*
43 *Onthophagus queenslandicus*
44 *Onthophagus quinque-tuberculatus*
45 *Onthophagus rubescens*
46 *Onthophagus rubrimaculatus*
47 *Onthophagus rufosignatus*
48 *Onthophagus tabellicornis*
49 *Onthophagus tamworthi*
50 *Onthophagus tenebrosus*
51 *Onthophagus thoreyi*
52 *Onthophagus wakelbura*
53 *Onthophagus waterhousei*
54 *Onthophagus worooa*
55 *Onthophagus yaran*
56 *Onthophagus yeyeko*
57 *Onthophagus* sp. nov. 1
58 *Onthophagus* sp. nov. 2
59 *Onthophagus* sp. nov. 3
60 *Coptodactyla glabricollis*



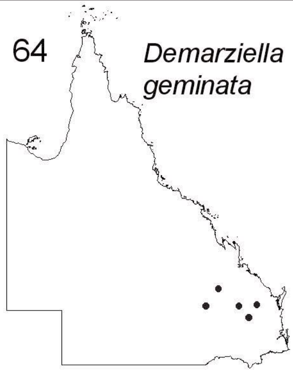
61 *Coptodactyla meridionalis*



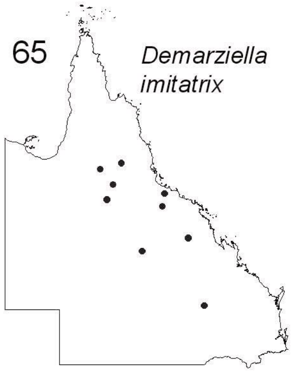
62 *Coptodactyla monstrosa*



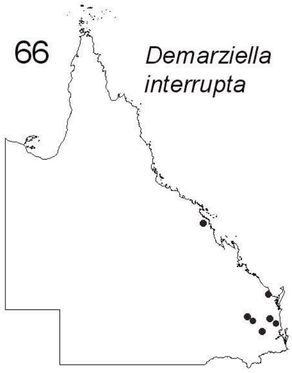
63 *Coptodactyla onitoides*



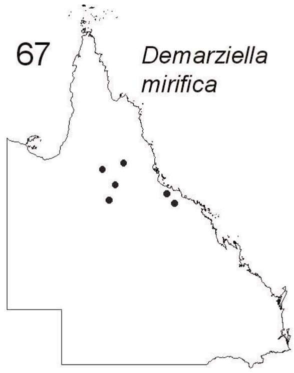
64 *Demarziella geminata*



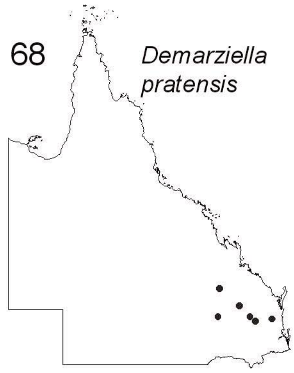
65 *Demarziella imitatrix*



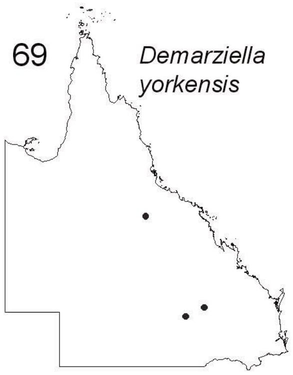
66 *Demarziella interrupta*



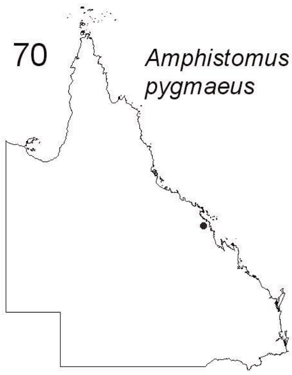
67 *Demarziella mirifica*



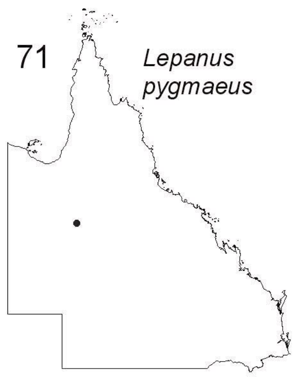
68 *Demarziella pratensis*



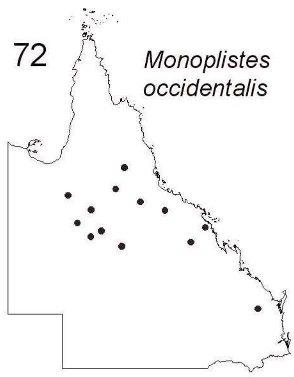
69 *Demarziella yorkensis*



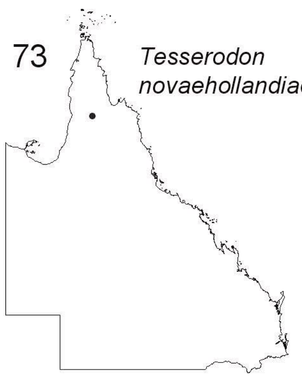
70 *Amphistomus pygmaeus*



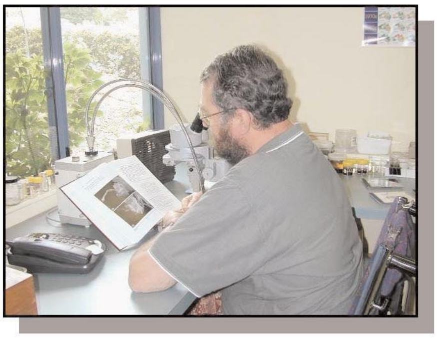
71 *Lepanus pygmaeus*



72 *Monoplistes occidentalis*



73 *Tesserodon novaehollandiae*



Ross Storey,
DPI Mareeba.

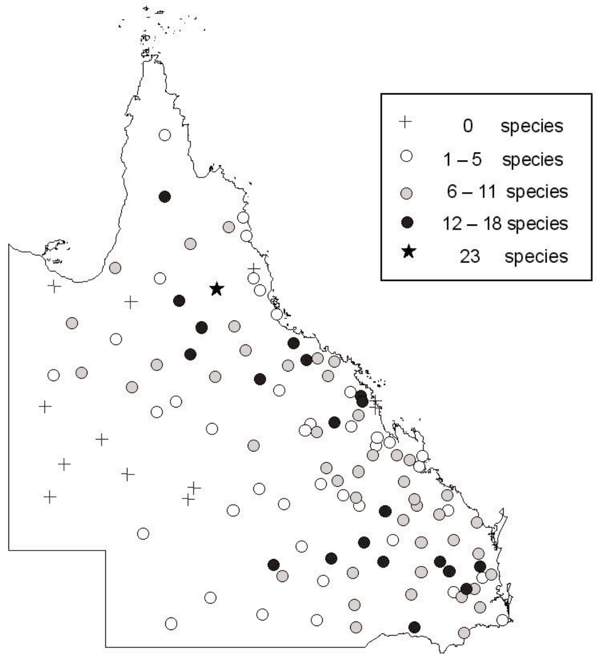
Ross identified all the native dung beetles collected during the Queensland Dung Beetle Project

iv) Species richness at each site

The number of species found at each site is shown in Figure 15. The maximum number of species recorded at one site was a remarkable 23 species at Mount Surprise.

Twelve sites had no native species. Very little trapping was undertaken at some of these sites, so the result may not be a true reflection of the situation. However extensive trapping was done at Malanda, and no native beetles were caught. Sufficient trapping was done at the dry far western sites to indicate that the lack of native dung beetles in cattle dung is probably a fair reflection of the situation in that area. Most of the high rainfall sites had very few native dung beetles (five species or fewer). These included the coastal strip from Cooktown to Ingham (six sites), Eungella and Numinbah Valley.

Figure 15. Number of species of native dung beetles trapped at each site (pitfall traps were baited with fresh cattle dung)



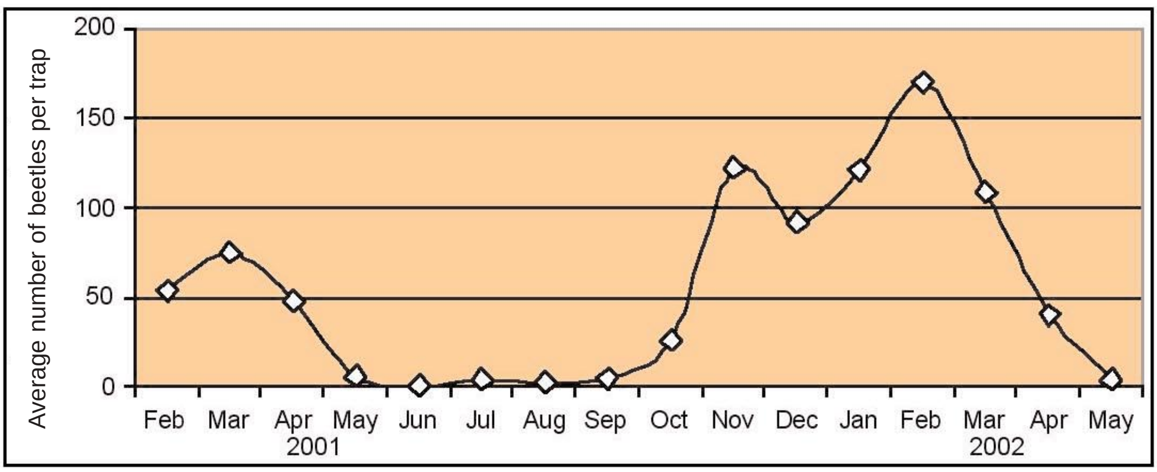
There were two regions where the diversity of native dung beetles was quite high (12 or more species). In southern Queensland the area bounded by Imbil, Goondiwindi, Charleville and Moura contained ten such sites. In north-east Queensland, the area bounded by Mackay, Moranbah, Richmond 3 and Musgrave contained 11 such sites.

v) Seasonal abundance of native dung beetles

The average number of native dung beetles caught per month is shown in Figure 16. These numbers represent all species combined. Most species were more active in the summer months than in the cooler months. An extreme example of this was *Onthophagus incanus*. From November to April it was recorded from between 15 and 30 sites. In contrast, there were no records at any sites from June to October, and the one record from May comprised a single beetle caught at Mitchell 1 on 9th May 2001.

Figure 16. Average number of native dung beetles per trap.

Results from all sites in Queensland have been combined.



There were a couple of interesting exceptions to the trend of very low activity in winter. *Onthophagus pentacanthus* was quite abundant in the winter months, and in fact was collected at more sites from May to October than it was from December to February. It is a large beetle, and 16 were caught in one trap at Charleville 2 in June 2001. Thus *Onthophagus pentacanthus* may be burying quite a large amount of dung in the winter months. Its distribution is restricted to the central part of southern Queensland (it also occurs further south, as far as South Australia). *Onthophagus tamworthi* was collected at quite a few sites in the cooler months, but even so, was more abundant in the warmer months.

vi) Notes on some native dung beetle species

Species in **Group A** are characterised by their large size. *Onthophagus atrox* (Figure 13c) was the fourth most widespread species, occurring predominantly in the south-east third of the state. It, and *Onthophagus quinquetuberculatus* (Figure 13b) were quite abundant at times, and were frequently observed burying large amounts of cattle dung. *Onthophagus pentacanthus* (Figure 13a) was quite common during winter, at a time when numbers of other dung beetles are very low. These large species may have evolved with the large herbivorous marsupials (such as *Diprotodon* species) that were once common in Australia. When these marsupials became extinct, the large dung beetles may have lost their main food supply. The arrival of cattle and their large moist dung pads may have once again created a highly suitable food source for these species. This is only speculation, and a study comparing the dung preferences and performance of these species on cattle dung and marsupial dung could yield interesting results.

Three of the species in **Group D**, *Onthophagus muticus* (Figure 13g), *Onthophagus parvu*s (Figure 13h) and *Onthophagus peramelinus*, have prehensile claws (not visible in the photos). These claws enable the beetles to cling to the fur of wallabies, particularly around the anus. When a pellet of dung appears, a beetle will attach to it and fall to the ground, and bury the pellet intact.

Among **Group M** are the two most widespread species, *Onthophagus consentaneus* (Figure 13r) and *Onthophagus rubrimaculatus* (Figure 13t). Matthews (1972) observed that *Onthophagus consentaneus* has the most widespread distribution of any Australian *Onthophagu*s species. He recorded that it may be found under decaying mushrooms and under vertebrate carcasses. Additionally it is strongly attracted to human excrement, and to a lesser extent to cow dung. Matthews commented that, surprisingly, it had never been found in or under marsupial pellets. Matthews suggested that its great abundance "appears not to be supported by the indigenous marsupial fauna, but, directly or indirectly, by man through his own excrement and that of his cattle and through the roadside slaughter that is a consequence of motor traffic".

vii) Average abundance of native dung beetles

As with the introduced species, a useful way to assess the overall activity of native dung beetles at a site is to look at the average trap catch over all months. Table 4 presents the average trap catch of native dung beetles throughout the year, at the 72 sites where 18 or more samples were collected. (These are the same sites used for the analysis of introduced beetle catches in Table 2).

The highest average trap catch was 1,084 native dung beetles at Richmond 3. Sixteen species were collected at this site, and many of these were very small species. The top ten sites, with an average trap catch of more than 140 native beetles, were Richmond 3, Chillagoe, Collinsville, Tara, Ayr, Mount Surprise, Goondiwindi, Stanthorpe, Einasleigh and Georgetown 1.

The lowest average trap catch of native beetles was 0 at Malanda (traps were set 26 times at this site – i.e. two traps for 13 months). The ten poorest sites for native beetles, with an average trap catch of fewer than three beetles, were Malanda, Tully, Daintree, Taroom, Rockhampton 1, Numinbah Valley, Clermont 3, Clermont 2, Marlborough 2 and Aramac.

There were five sites that were in the list of the bottom ten sites for both introduced and native beetles. These were Tully, Daintree, Malanda, Numinbah Valley and Aramac. With the exception of Aramac, these are amongst the wettest sites in the state. (Note that many of the far western sites did not collect 18 samples, so are not included in this analysis. Thus, Aramac is probably not exceptional for that part of the state).

Ayr was the only site that was in the top ten list for both introduced and native beetles.

Table 4. Average number of native dung beetles caught per trap catch at each site (only sites where at least 18 samples were collected are included)

Location	Average number of native dung beetles per trap catch	Total number of native species
Richmond 3	1084	16
Chillagoe	391	7
Collinsville	353	10
Tara	233	11
Ayr	207	12
Mount Surprise	177	23
Goondiwindi	160	14
Stanthorpe	142	6
Einasleigh	142	15
Georgetown 1	141	16
Mitchell 1	124	12
Woodstock	123	15
Lakeland	123	9
Injune	103	17
Chinchilla	99	10
Bowen	83	8
Moranbah	79	17
Normanton	78	11
Gumlu	74	7
St George	66	10
Musgrave	64	17
Durong	61	18
Charleville 2	50	7
Charleville 1	44	13
Crows Nest	40	12
Julia Creek 1	38	5
Imbil	37	12
Jackson	37	15
Theodore	33	10
Gayndah	32	10
Nindigully	29	7
Kumbia	28	14
Maleny	27	6
Goodwood	24	10
Emerald	23	8
Highfields	22	8
Roma	22	9
Rosewood	21	9
Sapphire	19	10
Hughenden	18	11
Ravenshoe	15	2
Richmond 1	15	3
Monto	13	10
Clermont 1	10	7
Charters Towers 2	10	10
Marlborough 1	10	9
Julia Creek 2	9	6
Richmond 2	8	9
Rolleston1	8	8
Kilcoy	8	5
Miriam Vale	7	6
Mundubbera	7	7
St Lawrence	6	4
Quilpie	5	4
Blackall 1	5	5
Esk	5	6
Gympie	5	9
Nebo 2	4	6
Rockhampton 2	4	8
Mackay	3	12
Thangool	3	9
Cloncurry/Burketown	3	6
Aramac	2	6
Marlborough 2	2	5
Clermont 2	2	4
Clermont 3	1.4	3
Numinbah Valley	1.0	3
Rockhampton 1	0.9	3
Taroom	0.7	5
Daintree	0.2	2
Tully	0.1	1
Malanda	0	0

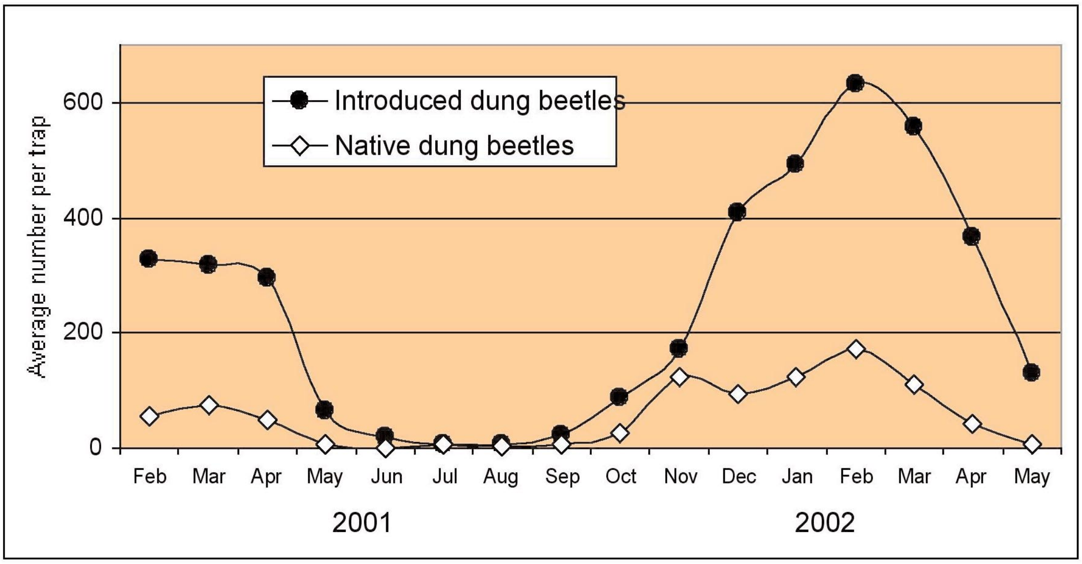
viii) Relative abundance of native and introduced dung beetles

Although this study has shown that many species of native dung beetles are attracted to cattle dung, and often in high numbers, it is pertinent to return to the introduced species, and compare the relative numbers of the two groups. Figure 17 shows the average number of beetles per trap of native dung beetles and the average number of introduced beetles per trap for each month of the project. The numbers of introduced beetles far exceeded the numbers of native beetles, particularly from December to April.

The impact of the difference in numbers of native and introduced beetles is even greater when it is remembered that the average size of introduced dung beetle species is much greater than the average size of native dung beetle species. As a rough guide, the larger the beetle, the more dung it will bury, although for many of the native species, little is known of their nesting behaviour. We do not know to what extent those species that are attracted to cattle dung will utilise it for feeding and breeding. However the large native species in Group A (especially *Onthophagus quinquetuberculatus*, *Onthophagus atrox* and *Onthophagus pentacanthus*) have been seen rapidly burying large amounts of cattle dung, and can clearly have a significant impact on its burial.

In spite of these general trends, there were sites where native dung beetles were quite abundant in cattle dung. There were nine sites where the number of native dung beetles trapped exceeded the number of introduced beetles. These were Stanthorpe, Richmond 3, Tara, Georgetown 1, Collinsville, Mount Surprise, Chillagoe, Maleny and Mitchell 1.

Figure 17. Comparison between average numbers of introduced dung beetles and average numbers of native dung beetles caught per trap in Queensland



5. OTHER PROJECT ACTIVITIES

i) Training Days

A total of 80 training days were held around the state, presented by the four DPI Project Officers. The training days were attended by 1,030 landholders. The content of the training days was prepared by Penny Edwards and Angus Macqueen, and developed for presentation in collaboration with the Project Officers.

The training program took about six hours, and topics covered included:

- Aims of the Queensland Dung Beetle Project and brief history of the introduction of dung beetles into Australia
- Dung beetle biology
- Results from local trapping sites
- Practical session on identification of introduced dung beetles
- Field demonstration on how to sample dung beetles
- The role of dung beetles in parasite control (especially buffalo flies and bush flies)
- The potential impact of veterinary chemicals on dung beetle populations
- Interactive forum.

Attendees were provided with instructions and equipment to collect their own dung beetle sample at home if they wished, and to send the specimens to Penny Edwards for identification. Participants were asked to attempt identifications of their samples. 159 samples were submitted, and participants received feedback on their specimens and a correct identification list.

These samples provided valuable additional distribution records for many species. The highlight was the discovery of *Onitis vanderkelleni* at Beechmont. Previously this species had only been recovered from the monitoring site at Ravenshoe.

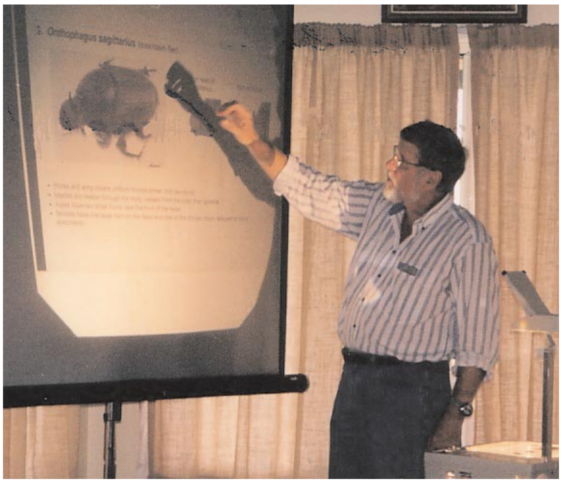
Participants completed evaluation forms at the end of each session. Attendees in all four regions rated identification of dung beetles as the most useful session. During this session participants prepared their own collection of pinned specimens of the eight most common species, learning the identifying characteristics of each species as they progressed.

A few of the many landholder testimonials from the training days:

"a very informative and thoroughly enjoyable training day"
"this is the most important project for the rural sector that I know of"
"a top day – all cattle producers should learn this information"
"a very important project for rural industry and the environment"
"we will make changes to our internal parasite management and control program"*
"I think every landholder should attend"
"should be further funding to ensure continuous monitoring with more monitoring of weather and chemical effects"
"an excellent presentation of this fascinating and essential topic"
"project should directly target schools to educate the younger generation"**
"a free lunch would be good"
"absolute top value"
"this has been excellent. Rural teenagers can actually be quite effective change agents. I hope that we can maintain the link and develop further projects in the future"
"would like to see the program continue for further research, and for more landholders to be involved as we have just begun to get aware and interested"

* The Project Management Committee has developed two informative brochures ("Consider your Dung Beetles when using Parasiticides" and "Strategic use of Parasiticides can help your Dung Beetles") that will be available from AgForce in mid-2003.

** The Project Management Committee has worked with the Department of Natural Resources and Mines to develop an educational module for schools called "Dungbusters". This can be accessed from the NRM website, and is also available from them on CD.



The popular Dung Beetle Training Days were held around the state

ii) Redistribution of dung beetles

Analysis of the data gathered from around the state revealed that most of the introduced dung beetle species established in Queensland have probably reached the limits of their potential distribution. This was based on an assessment of how far and how fast they had spread since the original releases were undertaken, together with a comparison of the known distribution in the countries of origin. However there were three notable exceptions to this. *Copris elphenor, Onitis caffer* and *Onitis vanderkelleni* were all locally abundant but very restricted in their distributions.

Copris elphenor and *Onitis caffer* were studied in South Africa during the CSIRO Dung Beetle Project, so considerable information is available on their biology and life cycles. Both species are capable of burying large amounts of dung.

Copris elphenor buries dung extremely rapidly, usually overnight, to provision an underground chamber. The dung is then divided into two to four individual dung balls, and an egg is laid in each. The female dung beetle remains in the nest to care for her developing offspring. This high level of parental investment means survival of progeny is high. Populations can build up to high levels and be maintained at relatively constant levels from year to year. However a feature of this sort of reproductive strategy is that the adult beetles generally do not disperse very far. *Copris elphenor* has spread in a radius of about 50 km in the 20 years since its release at Biloela. A small release at Roma failed to establish. It is particularly active in spring and early summer, but is present through to autumn. Its rapid rate of dung burial makes it very effective against buffalo fly. It potentially has a wide distribution in Queensland (Figure 18). It is particularly well suited to sandy soils, and does better in drier warmer areas than many other species.

Onitis caffer buries dung in a more sustained manner than most other species. Because it is active in autumn and early winter, there is little competition from other species. For this reason it can remain in a dung pad burying dung for up to two weeks, or for as long as suitable dung is still available. It has a developmental diapause (arrested development), which prevents the larvae from completing their development until the following autumn. It makes its nest very deep in the soil, up to a metre in soft sandy loam, but shallower in a harder soil. This species also has a low dispersal rate. It has spread approximately 70 km since its release at Highfields 20 years ago. This was the only site where the summer rainfall strain of this species was released. Its activity in autumn and early winter make it a very useful addition to the dung beetle fauna. Its potential distribution includes a large part of south-east Queensland (Figure 18).

The reason so few releases of the above two species were made by CSIRO is because the biology of the beetles made them very difficult to breed in the laboratory. All dung beetles introduced to Australia were sent as eggs. These eggs had to be reared to adults in quarantine, and then another generation reared, also under quarantine conditions. For a species with parental care, such as *Copris elphenor,* and a species with a developmental diapause, such as *Onitis caffer*, this was a labour intensive, time consuming and difficult process.

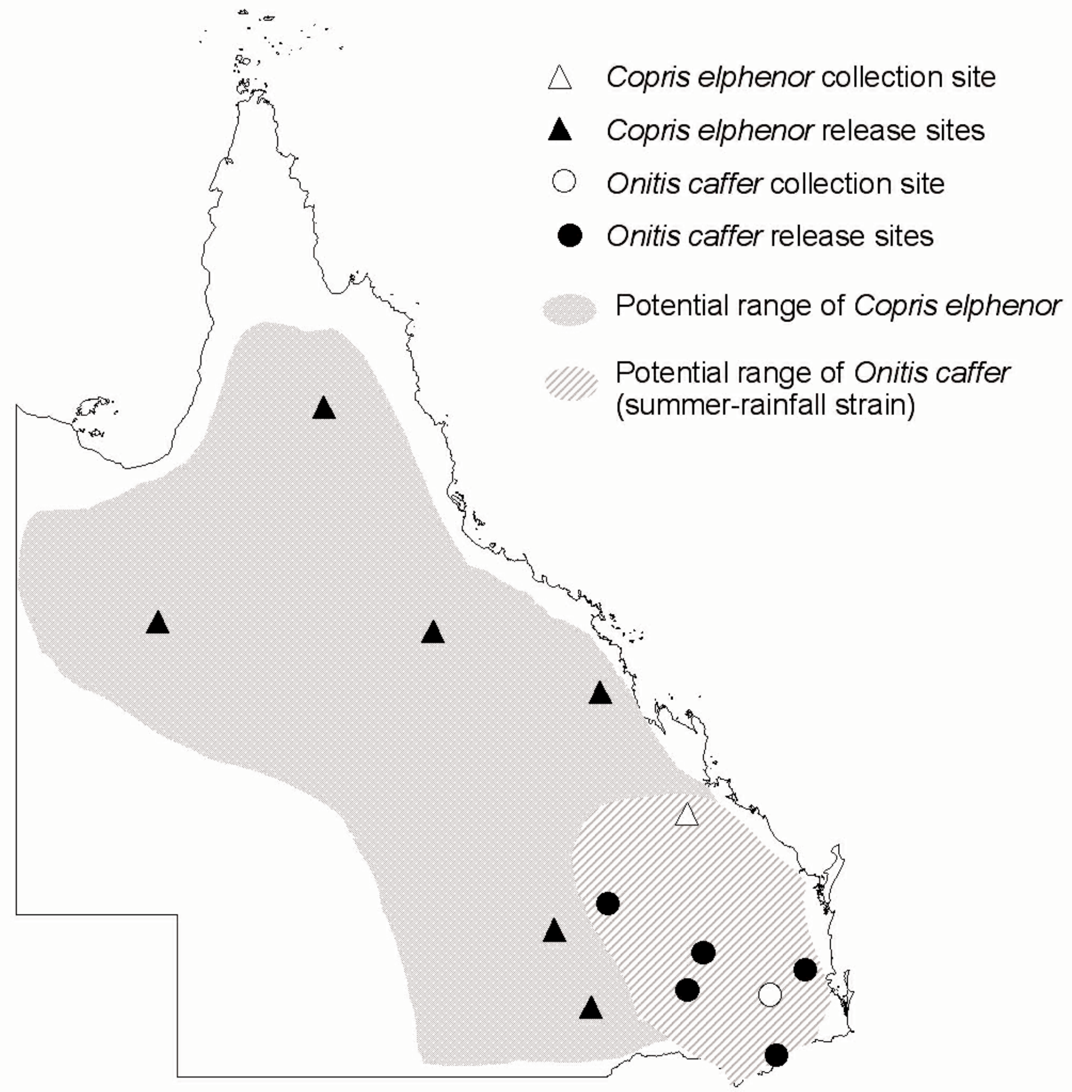
Onitis vanderkelleni originates from the highlands of Kenya. It was released at several sites in eastern Queensland, but appears to have established at only two of these, at Beechmont and in the Ravenshoe district. It is one of the few species suited for high rainfall regions.

The decision was made that these three species were the most suitable candidates for redistribution. Although they are slow dispersers, they have desirable attributes and are capable of making a significant contribution to dung burial.

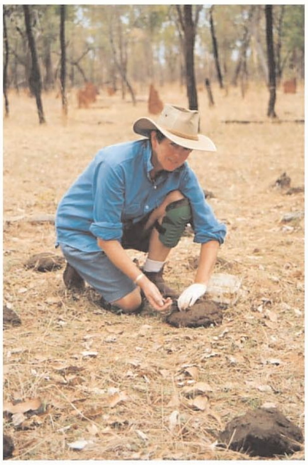
Collection, maintenance and release of dung beetles is a labour intensive process. Care was given to maximise the survival of beetles during collection and prior to release, and the best conditions were provided to enhance the chances of establishment at the new site. Protocols were developed to ensure that the risk of transfer of weed or disease organisms was minimized. Release sites were selected within the known climatic range of each species. The intention was to establish colonies of each species across its potential range in Queensland, providing sources for future redistribution in the years ahead. Preference was given to landholders who had been involved in the trapping program.

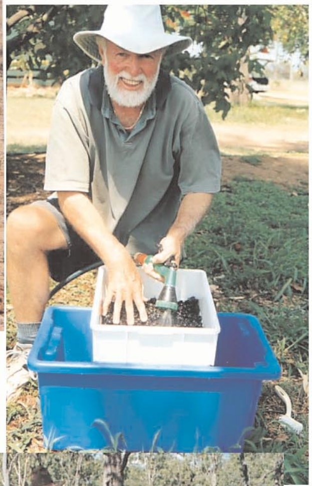
Onitis caffer was collected near Toowoomba, and *Copris elphenor* was collected near Biloela (Figure 18). By January 2003, five releases of *Onitis caffer* (at Injune, Chinchilla, Tara, Kilcoy and Stanthorpe) and six releases of *Copris elphenor* (at Nebo, Cloncurry, Chillagoe, Surat, Pentland and Mitchell) had been completed (Figure 18). Six more releases of *Onitis caffer* and one release of *Onitis vanderkelleni* are planned to be completed by June 2003. By the end of April 2003, releases of *Onitis caffe*r had been made at Mundubbera, Gayndah, Jackson and Goondiwindi.

Figure 18. Redistribution of *Copris elphenor* and *Onitis caffer*



Dung beetle redistribution activities around the state









6. CONCLUDING REMARKS ON THE QUEENSLAND DUNG BEETLE PROJECT

The 2001-2002 Queensland Dung Beetle Project has provided the first comprehensive and quantitative survey of introduced and native dung beetles in cattle dung in Queensland, indeed in Australia. It evaluates the success of species introduced by CSIRO in the 1970s and 1980s, by providing a record of their establishment, extent of spread, and seasonal and geographic abundance. This will enable informed decisions to be made about any future introductions or redistribution of dung beetle species in Queensland.

The survey provides a detailed snapshot in time, which can be used as a reference point for future studies. The continued spread of the introduced species, the establishment of redistributed colonies or of future introductions, and the ongoing status of native dung beetles in cattle dung can be assessed in relation to the current knowledge as presented in this report. Thus the 2001-2002 Queensland Dung Beetle Project will serve as a benchmark for any future studies in Queensland. It could also provide a model for similar projects that may be undertaken elsewhere in Australia.

The information acquired during the survey was used to select three species for redistribution within Queensland (*Onitis caffer, Copris elphenor* and *Onitis vanderkelleni*). Redistribution work was initiated, and with further funding, additional redistributions could be undertaken. This should be regarded as a priority for two of the species (*Onitis caffer* and *Copris elphenor*), which are only spreading slowly at present.

The project has produced surprising information on the diversity and abundance of native dung beetles in cattle dung. It has shown that in some areas native dung beetles are likely to be having a significant impact on the burial of cattle dung.

Another outcome of the project is the confirmation of the outstanding success of the original CSIRO program to select and introduce dung beetles into Australia. Fifteen introduced species were collected during the project, and many of these have spread widely. The steady stream of large samples of introduced dung beetles received from most parts of Queensland for many months of the year provides validation of the long-term investment in the CSIRO program. Those beetles serve as an indicator of the extent of dung burial that occurs around the state during the spring to autumn months. The impact of this on soil, water and pasture health, and on control of pest flies is undoubtedly worth many millions of dollars a year.

Dung beetles, both native and introduced, are a valuable natural asset. Their combined contribution to the health and productivity of our land is significant, although difficult to quantify. They are a sustainable and renewable resource that should be nurtured and protected. One way we can do this is through informed use of veterinary chemicals. To this end, project staff, through AgForce Queensland, have prepared two notes to help cattle producers select and use chemicals that will minimize the risk of harming their dung beetles. These notes are based on a literature survey that was undertaken for the National Dung Beetle Planning Forum by Keith Wardhaugh of CSIRO Entomology. The notes will be available from AgForce in mid-2003.

The project generated much community interest and involvement. The inclusion of landholders in the dung beetle survey greatly increased the scope and impact of the project. It enabled the collection of much more data from a wider geographic spread than would otherwise have been possible. Through their participation, landholders also increased their own awareness and knowledge of the benefits of dung beetles. Each participating landholder received a detailed Property Report by December 2002 on the dung beetles they had collected. This Final Report represents a distillation of those 123 Property Reports, and provides a vehicle for disseminating and sharing the knowledge acquired during the project.

The interest in dung beetles and demand for information from the wider community was largely met through the dung beetle Training Days held around the state. The response to these events was very positive. This part of the project was highly successful in spreading knowledge and understanding of dung beetles to all parts of the community. Finally, the development of a schools' package (Dungbusters) will ensure that an appreciation of the benefits of dung beetles will be passed on to the next generation of land managers.

The contribution of the Natural Heritage Trust to this successful community based project is again gratefully acknowledged.

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