SECTION 4

The Future

REVIEW AND RECOMMENDATIONS FOR THE FUTURE

The proceeding three sections have provided information on the introduction and current status of introduced dung beetle species in Australia.

The final section looks at the future.

The first part (pages 44-48) covers several aspects of dung beetle field activities and data acquisition, and provides recommendations for ensuring that appropriate redistribution work is undertaken and for keeping our knowledge base up-to-date. A brief outline is provided of the steps required to introduce new species of dung beetles into Australia, and lists some of the preparations and requirements for achieving a successful introduction program. Topics covered in this first part are:

- Distribution data
- Native dung beetles
- Redistribution of dung beetles
- Seasonal data
- Collating and archiving data
- Future introductions

The second part (pages 49-65) presents a discussion forum. Ideas and opinions were sought from members of the original CSIRO dung beetle project team. Contributors were invited to discuss future dung beetle activities, particularly in relation to further introductions. They were invited to nominate any species they felt were worthy of consideration for introduction into Australia.

Label used during CSIRO Dung Beetle Project

DISTRIBUTION DATA

Up-to-date information on dung beetle distributions assists in planning redistribution activities, as well as increasing preparedness for selecting species for future introductions.

The distribution data compiled in this report have come from a wide range of sources, covering a period of forty years. A particularly useful source of data was the CSIRO Double Helix Science Club project "Dung Beetle Crusade". Nearly 700 participants around Australia collected dung beetles during the summer and autumn of 1994/5.

It would be timely to undertake a similar Australia-wide sampling project. This could be run by Double Helix, or through a schools network, or by Landcare Australia. It would be desirable that it have good regional structure, to ensure that all areas were well represented in the sampling effort. Feed-back should be provided to participants, so that knowledge and appreciation of dung beetles continues to be disseminated.

It is essential that the results of such projects are made widely available in the form of a report or publication.

NATIVE DUNG BEETLES

This review has largely ignored the role of native dung beetles in dispersing cattle dung. The Qld 2001-2002 Dung Beetle Project revealed that at some locations native dung beetles were more numerous than introduced dung beetles in cattle dung. Numbers of beetles can be misleading, since many of the native species are quite small. However where larger species are abundant, particularly members of the 'atrox' group (e.g. *Onthophagus atrox, O. ferox, O. quinquetuberculatus, O. pentacanthus, O. pugnacior*), their contribution to dung burial can at times be quite substantial. Significant burial of cattle dung has been recorded for *O. ferox* in WA, *O. pentacanthus* in SA and *O. granulatus* and *O. australis* in southeast Australia.

Onthophagus pentacanthus

Little is known about the nesting behavior of most native species. It would be useful to obtain data for the key species that utilize cattle dung in relation to the depth of dung burial, the pattern of dung burial (days after pad colonization) and seasonal activity and abundance. It would also be valuable to determine the nature and outcome of competition in cattle dung between native and introduced species.

Two interesting suggestions regarding native dung beetles are raised in the discussion forum (to follow). The first, by James Ridsdill-Smith (page 62), is to undertake research to determine if introduced dung beetles are having any impact on native dung beetles in undisturbed habitats. The second, by Bernard Doube (page 55), is to consider redistributing native dung beetles to improve the burial of cattle dung.

REDISTRIBUTION

Strategic redistribution work should be undertaken, to assist slow spreading species reach their potential distribution as rapidly as possible. The predicted distribution maps presented in this report should be used as a guide, and careful consideration should be given before investing in redistribution beyond the boundaries indicated on the maps.

A small brochure should be produced, to provide a summary of the species recommended for redistribution, and areas suitable for such redistribution. This brochure would serve as a support document for regional and local groups seeking funding to undertake redistribution work.

Comparison of actual distributions and predicted distributions of introduced dung beetle species (Section 2) indicates that the following species are the most suitable for further redistribution:

SPECIES	CURRENT DISTRIBUTION	AREAS SUITABLE FOR REDISTRIBTUION
Bubas bison	Southern WA, SA and Vic	Southern WA and SA, southern/inland NSW, most of Vic.
Copris elphenor	Nr Jambin Qld	Eastern Qld, northern NSW, possibly Central Australia.
Copris hispanus	Nr Williams WA	Southern WA and SA, southern/inland NSW, most of Vic.
Geotrupes spiniger	Tas, Vic, southern NSW	Widely through Vic, Tas and southern NSW, possibly small areas in SA and WA.
Onitis aygulus	Scattered through southern WA, SA, Vic and NSW.	Southern Australia (except Tas) through to southeast Qld.
Onitis caffer	Near original release sites in WA, NSW and Qld.	Southern Australia through to southeast Qld (winter-rainfall and summer-rainfall strains where appropriate).
Onitis vanderkelleni	North Qld and southeast Qld	High rainfall areas of Qld highlands and coastal NSW
Onthophagus obliquus	Cooktown [current status requires confirmation]	WA (Kimberley region) , parts of northern NT

These recommended species are predominantly those that were difficult to breed and hence only low numbers were available for release.

The difficulties encountered in breeding these species were largely a result of larval diapause (e.g. *Bubas bison, Onitis caffer*) or parental care of offspring (both *Copris* species). These characteristics are typical of 'K selected' species, species which compete successfully for limited resources and are able to maintain steady and high population levels. Such species tend to be large, have a long life span, produce fewer offspring that are well cared for, and spread slowly. Hence these species benefit greatly from redistribution.

In contrast, 'r selected' species are species that do not compete successfully for resources. They tend to have a high reproductive rate, small size, short generation time and disperse widely and rapidly. These features made them easy to breed, and hence they were released in large numbers, and they spread rapidly and widely. There is now little to be gained by further redistribution of these species (most of the *Onthophagus, Euoniticellus, Sisyphus* and some *Onitis* species).

How successful have recent redistributions been? Two redistribution programs in the last six years have been well documented, and provide a good opportunity for determining success rate in establishment. The programs were conducted by the Northern Tablelands Dung Beetle Express and the Qld 2001-2002 Dung Beetle Project. The two main species that were redistributed between 2001 and 2006 were *Onitis caffer* and *Copris elphenor*. For both these projects good records exist of numbers of beetles released, date of release, methodology used and weather conditions since the release. It would be instructive to survey the release sites and determine where the species have established. Other redistribution programs could be included in the review if suitable records exist. This would allow a reassessment of redistribution methodologies to be undertaken, resulting in the production of recommended protocols for those wishing to undertake redistributions.

Protocols for redistribution. State regulations should be consulted before undertaking redistribution of dung beetles. Minimum requirements for safe redistribution include washing beetles at the collection site (to remove weed seeds, soil and dung) and transporting them in clean damp peat moss (or similar medium) with no dung. If they are to be stored, they should be fed on dung that has been frozen, and then thawed as required. Prior to transport to the release site they should again be washed and packed in clean damp peat moss, and transported without dung.

SEASONAL DATA

This report concentrates on geographic distribution, rather than seasonal distribution of species. To make informed decisions about future introductions, the seasonal gaps in activity are equally as important as the geographical gaps. These data are much harder to gather, particularly as there are great variations from one year to the next. The Queensland Dung Beetle Project (2001-2002) serves as an excellent model on how this type of information can be acquired. Approximately 120 trapping sites were set up around the state and these were monitored once a month for a year by landholders. The samples were submitted to coordinators and identified by trained staff.

A similar project could be attempted nationwide, but would need to be more strategic in approach to avoid a huge workload in processing the samples. For example, 50 locations could be selected around Australia, to provide good representation of the major climate regions and major cattle producing areas. Local Landcare groups could co-ordinate the project by selecting landholders willing to do the trapping, and ensuring samples were collected and submitted to a central location (or state centres) for sorting and identifying. Reimbursement of landholders could be considered, as this may result in greater commitment to the project. Ideally two years would be required to allow for major differences between years.

Other data on the seasonal abundance of dung beetles exist, and all sources should be combined to create the most complete record possible.

Native dung beetles should be included in seasonal surveys.

COLLATING AND ARCHIVING DATA

In compiling this report it has become apparent that a wealth of relevant information exists. Much of it is accessible (scientific papers, museum collections, reports, CSIRO archives, etc), but a considerable amount resides in the hands (and minds) of individuals. Many of these individuals were part of the original CSIRO Dung Beetle Project, and most are nearing, or have reached, retirement. Every effort should be made to record as much of this information as possible, before it is lost. The invited contributions to the discussion forum provide an indication of the depth and extent of experience and knowledge that exists, but much more still resides in filing cabinets, note books and memories. Perhaps the CSIRO Entomology archives could be used as a repository for any existing unpublished or un-catalogued data. A history of the dung beetle project could be commissioned, to compile the full scientific and personal stories associated with such an ambitious project.

FUTURE INTRODUCTIONS

Steps required to bring about the introduction of new species include the following:

1. Demonstrating the need
2. Selecting candidate species
3. Obtaining funding
4. Ensuring quarantine arrangements in place
5. Arranging collection and importation of beetles
6. Rearing in quarantine
7. Releasing
8. Monitoring

1. Demonstrate the need

To mount a convincing case to introduce new dung beetle species into a region, it first should be demonstrated that there is an ecological niche that needs to be filled (e.g. a geographical, habitat or seasonal gap). The distribution data used in this report can be used as a starting point, but more detailed local distribution data would probably be required, and would certainly be helpful.

Seasonal data of existing dung beetle activity are available for some regions, and would need to be collated from published literature, project reports and unpublished sources. Additional data may be required for many regions. Seasonal gaps in activity can then be highlighted.

For some areas the needs are already clear. A gap in early spring activity has been identified in many regions, and species are available that could help fill this gap. However not all requirements can be met. For instance there are very few winter-active species in summer rainfall areas of Africa, thus it is a niche that is unlikely to be adequately filled in Australia.

In general terms, there is a need for better quantification of the benefits of dung beetles. Their impact on fly and parasite control, pasture productivity, nutrient cycling, water quality, and soil health are well-known but poorly-documented. If it can be demonstrated that an increase in dung beetle activity will result in an increase in these benefits, then the case for further introductions becomes stronger.

2. Select the species

Species need to be selected that will fill the geographic, habitat and seasonal gaps identified in (1). Geographic suitability in essence reflects climatic suitability. Modeling programs are available that allow prediction of the potential distribution of a species, based primarily on the climate in the country of origin. It is essential that this is done as accurately and carefully as possible, and should include an assessment of the reliability of overseas distribution records. Seasonal data are available for many overseas species, and can be found in published papers, theses and CSIRO archives.

Additional factors to be considered are the soil and habitat preferences of selected species. Care should be taken to avoid selecting species that will simply add to the competition between existing species (introduced and native).

There is no shortage of species from which to select. Many are mentioned in the forum section (pages 49-65). As well as ‘new’ species, the species that were not released from quarantine should be reconsidered. Also, the predicted distribution of released species that failed to establish should be modeled to determine if climate contributed to their failure.

There are likely to be competing claims regarding species selection from different parts of Australia. This will partly be resolved by the funding source. If funding comes from a regional source, then clearly species suited for that area would be selected. If national funding became available, then decisions would need to be made as to which species could potentially provide the greatest national benefits.

3. Obtain funding

The main costs to be included in a funding application will be associated with collection and importation of beetles, the use of quarantine facilities in Australia and staff to rear the beetles. Sources of funding could include agricultural industries (beef, dairy, wool), environmental sources (NHT, Landcare), and companies and individuals. Dung beetles have popular appeal, and could provide a good public image for a supporting company.

4. Establish quarantine requirements

Quarantine requirements are probably the most difficult and expensive part of a dung beetle importation exercise. Dr Keith Wardhaugh has made some suggestions on how quarantine issues could be approached (page 64). Careful planning, including early liaison with AQIS, needs to be addressed, before any importation project can be planned.

5. Collection and importation of beetles

Two former CSIRO dung beetle project staff currently live in South Africa and France. It might be possible to contract these people to undertake the collecting and preparation of beetles for shipment, as both have great familiarity with the beetles and the procedures required. Failing this, collectors would have to be sent from Australia to undertake the work, which would entail greater expense and be less efficient.

6. Rearing beetles in quarantine

Much was learned during the importation phase of the CSIRO Dung Beetle Project. Species differ in their rearing requirements, and species with a developmental or reproductive diapause present additional difficulties. At the time of the original introductions, many species were being reared concurrently, often in the absence of detailed information on their requirements. As John Feehan points out (page 57), many of the species that failed during the original importation program, could now probably be reared successfully. Similarly, new species could probably be reared effectively by drawing on the vast amount of experience and knowledge gained during the CSIRO project and subsequently.

7. Release conditions for beetles

A brief analysis of the establishment of new species (in Section 1) revealed that a minimum number of release sites and beetles per release site were associated with successful establishment. These figures could be used as indicators of basic requirements.

Releases should be given the very best chance of survival and establishment, by careful site selection (assessing soil type, minimizing risk of flooding, etc), providing a good supply of good quality dung in a localized area, and by pre-watering the soil if conditions are dry (see comments by Angus Macqueen, page 60). Release of a new species warrants much more care and attention than can generally be given to redistributed beetles.

8. Monitoring of beetles

Regular monitoring at and near release sites should be undertaken to provide feedback on establishment. The likely time to establishment can be estimated from the times recorded in the past (Table 1, page 2). Once establishment is confirmed and the population is flourishing, redistribution should be commenced to reduce the risk of local extinction which could result from a range of causes such as inappropriate parasiticide use, local drought, or other unforeseen circumstances. Involvement of local land-owners and Landcare groups would be beneficial for stages 7 and 8.

DISCUSSION FORUM

Contributions to this discussion forum were invited from members of the original CSIRO Dung Beetle Project.

Contributors were invited to provide comments and opinions on future dung beetle activities, particularly in relation to further introductions. They were also invited to nominate any species they felt were worthy of further consideration for introduction. The comments reflect the unique experience of each contributor during the CSIRO Dung Beetle project. Most of these former staff members had overseas experience during the dung beetle project, and their comments represent a vast wealth of combined knowledge and experience.

I am particularly grateful for these contributions. I feel it is really valuable to conclude this report with a range of views which will provide a starting point for future deliberations.

The contributions are presented alphabetically, which provides the happy coincidence of starting with the ‘father’ of the dung beetle project, Dr George Bornemissza. George provides some insights into beetle selection and particularly how this was tackled in the early stage of the project. The last words go to Dr Jane Wright, who is still with CSIRO Entomology. Jane is thus able to provide some comment from within the organization about future dung beetle activities and how to work towards further introductions.

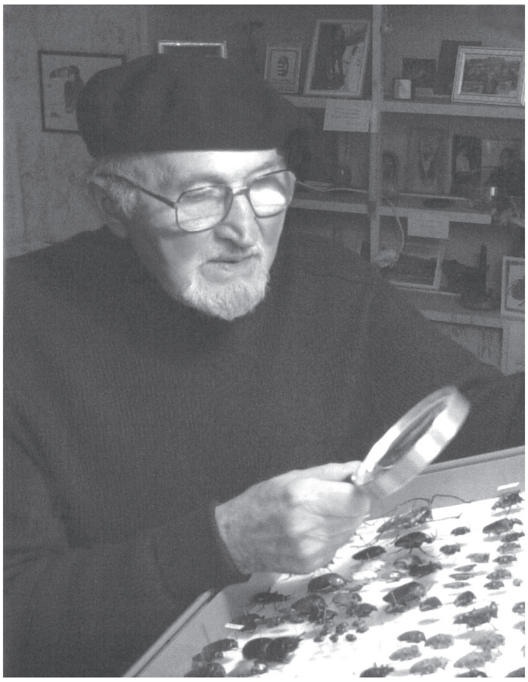
The contributors:

- **Dr George Bornemissza**
- **Dr Adrian Davis**
- **Dr Bernard Doube**
- **Dr Penny Edwards**
- **John Feehan**
- **Grant Flanagan**
- **Dr Alan Kirk**
- **Dr Angus Macqueen**
- **Karen Olsen (Paschalidis)**
- **Dr James Ridsdill-Smith**
- **Dr Marina Tyndale Biscoe**
- **Dr Keith Wardhaugh**
- **Dr Jane Wright**

DR GEORGE BORNEMISSZA

Dr George Bornemissza was the creator and first leader of the Australian Dung Beetle Project. George was based in South Africa from 1970 to 1979, and during that time conducted extensive surveys through Africa, Europe and Asia. Many of the species originally selected by George have already been successfully introduced into Australia.

George has provided comments on the criteria he applied in selecting dung beetles for Australia during the period of the original introductions. He believes that these principles still apply today:



"The two over-riding principles were that the beetles do not cause any harm to the biota or the environment, and secondly that the interests of the endemic dung beetle fauna are protected. My overall strategy was to have beetles bury or shred cow pads within 48 hours after dropping, in order to destroy pest flies and parasites that breed in cattle dung. I wished to create an effective dung beetle community, or 'mini-fauna', in every habitat.

The main selection criteria I used were:

1. *Efficient dung burial. Species that bury dung in the shortest time were given priority.*
2. *Reproductive capacity. Initially fast breeding species were selected, firstly as they are easier to breed, and secondly to achieve visible impact early in the project. The slow or difficult breeders were set aside for more detailed attention when time and staff permitted.*
3. *Bovine dung feeders. Preference was given to species that were largely restricted to cow dung. This was mainly to protect the native dung beetles that utilize marsupial dung.*
4. *Geographic distribution. Close attention was paid to species with a wide geographic distribution, especially across several climate zones. It was felt that these might be more adaptable to Australian conditions.*
5. *Co-adaptation. Care was taken to match types of beetle activity to reduce inter-specific competition.*
6. *Climate matching. This was an integral part in the selection of every species, including 'subclimatic' strains if there was any need for their separate treatment.*

The introduction of exotic dung beetles and their subsequent establishment in Australia is now history, and a very successful one at that. However, it fell short in filling all the climatic areas with their vast variety of habitats due largely to the premature closure of the Dung Beetle Project. By invitation, I'll attempt to fill some of those gaps with a list of desirable species, based on my own observations on four continents over a span of forty years."

George's list of desirable species follows. He provided full details on each species, and summaries of these are provided in the table.

GEORGE BORNEMISSZA'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Oniticellus tesselatus	Wet tropics	S. India, Sri Lanka, Java	Coastal sand; active at end of monsoon and into dry season. Tolerates shade.
Liatongus venator	Wet tropics	Bombay to Java, S. China	As above. Also in human and dog droppings.
Liatongus vertagus	Wet tropics and subtropics	Assam – SE Asia, S. China	Sand and sandy loam. Tolerates high rainfall (>1200mm).
Liatongus rhadamistus	Wet tropics	India – Burma, SE Asia	Well-drained loams and heavy loams. Pastures to forest edges.
Heteronitis castelnaui	Wet tropics	Kenya, eastern Africa to S. Africa	Sandy loams to clay. Elephant/rhino specialist, but also buffalo/cattle, "ferocious diggers"
Heteronitis tridens	Wet to dry tropics	Senegal to Nigeria/ Cameroon	Savanna woodland, sandy loam/clay. Cattle dung; excellent dung disposal.
Onitis curvipes	Dry tropics	Botswana/Namibia	Loams, rangelands and pastures. Good and rapid dung burial.
Onitis robustus	Wet/dry tropics	Zimbabwe - Namibia	Sparse woodland, savanna, pastures. Good dung disposal. In areas subject to drought.
Onitis belial	Winter rainfall	Central and west Mediterranean	Sandy to heavy loams. Excellent and rapid dung disposal. Active from early spring.
Onitis humerosus	Winter rainfall	East Mediterranean to Turkey/Iran	Loams. Strong preference for cow dung. Active as soon as snow melts. Excellent dung burial.
Onitis subopacus	Semi wet tropics	Afghanistan – Pakistan, India	Loams, gravelly. Higher altitude species. Good tolerance for shade. Good cow dung burial.
Onitis philemon	Wet tropics	India – SE Asia	Loam to heavy loam, pastures. A high rainfall species (2000mm).
Onthophagus gibbosus	Temperate winter rainfall	Mediterranean basin – Turkey/Iran	Loams. Numerous in parts of Turkey and Iran. Active later than *O. humerosus*, into May/June.
Onthophagus nuchicornis	Temperate winter rainfall	N. Mediterranean, Hungary - Turkey	Sandy/heavy loams. Numerous in S. Hungary. More cold hardy than *O. binodis* or *O. taurus*.
Onthophagus vacca	Temperate winter rainfall	N. Mediterranean, Hungary - Turkey	Sandy/heavy loams. Higher temperature regimes than *O. nuchicornis*.
Onthophagus sinicus	Wet tropics	Thailand-Malaysia – Sumatra - China	Sandy soils, sandy loams. High rainfall, monsoon species. Most effective on Lantau Is.
Onthophagus aciculatus, auriceps/brucei	Wet subtropics	Kenya – S. Africa	Coastal sands and dunes. Very efficient dung burial. Labour intensive to breed, but worthy of any investment of time and money
Onthophaugs alcyon	Temperate to wet tropics	Kenya to S. Africa, Zimbabwe, Nigeria	Sand to heavy loams. clay. First to appear at start of wet season. Tolerates runny, soft dung.
Onthophagus johnstoni	Wet tropics, prob. bimodal rainfall	Kenya – Tanzania – Malawi. Highlands	Volcanic loams, kikuyu pasture. Spectacular burial of bovine dung.
Onthophagus quinquedens	Wet tropics Summer rain-fall	Kenya – Mozamb. – Zimbab. Highlands	Volcanic loams, kikuyu pasture. Phenomenal capacity for dung burial.
Phalops ardea	Temperate, subtropics	Kenya to S. Africa	Sandy loam, loam. Savanna grasslands, pastures. Tolerant of green-grass scoury dung
Phalops smaragdinus	Tropics	Zimbabwe, rare in S. Africa	Sandy loam, loam. Savanna grasslands, pastures. Tolerant of green-grass scoury dung
Phalops wittei	Dry temperate - hot	S. Africa - Namibia	Sandy loam, loam. Savanna grasslands, pastures. Tolerant of green-grass scoury dung
Copris evanidus	Subtropics warm temp.	S. Africa, Botswana, Malawi, S. Mozamb.	Loams, heavy loams. Savanna, grassland. Like most *Copris*, not abundant. Good dung burier.
Copris fallaciosus	Subtropics warm temp, hot/dry	Mozam. Zamb, Bots. Zimb, S. Africa	Sandy to heavy loams. Savanna grasslands pasture. Not abundant, good dung burier.
Copris fidius	Temperate	S. Africa	Loams, clay. Grasslands pastures. Good cold/ wet tolerance. Also in shade at forest edge.
Copris repertus	Wet tropics	India – Sri Lanka - Thailand	Sand to heavy loams. Grasslands and pastures. Good dung burial.
Copris reflexus	Wet tropics	Malaysia - Java	Sand to heavy loams. Grasslands and pastures. Good dung burial.

GEORGE BORNEMISSZA'S SPECIES FOR FUTURE INTRODUCTION (ctd)

Copris signatus	Wet tropics	S. India - Sri Lanka - Burma - Thailand	Sand to heavy loams. Grasslands, pastures and light forest.
Copris sacontala	Wet tropics	Kashmir/Jammu – India – Sri Lanka	Sand to heavy loams. Grasslands and pastures. Cooler tropical regime, frost tolerant.
Copris sinicus	Wet tropics	Malaysia – S. China, Sumatra/Java	Sand to heavy loams, pastures, potentially a good burier, tolerance for some shade.
Copris lunaris	Cold temperate	Europe – Asia Minor, S. Russia	Loams to clay. An efficient frost-hardy species, mainly in hilly country.
Catharsius calaharicus	Warm/hot arid, erratic rains	Kalahari/Namibia to Kruger NP.	Sand, grass and shrub-land. Efficient dung disposer. Resilient to harsh conditions.
Catharsius platycerus	Wet tropics	Mozambique - Zimbabwe	Sandy to well drained forest soils. Rainforest beetle.
Catharsius tricornutus	Warm temp. to tropical.	Southern Africa	Sandy loam, well-drained loam. Savanna, sparse woodland, grassland. Excellent dung burier.
Catharsius ulysses	Warm/hot temperate	S. Africa (W. Cape Province)	Light and sandy loams, grassland, pasture. In cattle yards and camps. Excellent dung burial.
Catharsius capucinus	Wet tropics	India, Sri Lanka, Burma, Thailand	Heavy loam, clay, Pastures, forest edge. Tolerant of high rainfall (>2000mm) and sticky soil.
Catharsius pithecius	Wet tropics	India, Sri Lanka, Burma, Thailand	Loams, pastures, forest edge. Higher elevation than *C. capucinas*.
Catharsius molossus	Wet tropics	India, SE Asia, S. China, Taiwan	Sandy to heavy loams. Grasslands, shrublands, pastures. Widespread and versatile species.
Catharsius sagax	Wet tropics	India – SE Asia, S. China, Sumatra-Bali	Sandy to heavy loams, pastures, grasslands, shrublands. Tolerates high rainfall, sticky soil.
Catharsius harpagus	Sub tropics	Mozambique – S. Africa.	Coastal sand dunes, grassland, shrub land. Efficient all –year dung burial.
Heliocopris andersoni	Sub tropics	Kenya–S. Africa, Namibia - Congo	Sandy loams, aeolian sands, savanna, grassland, pasture. Efficient dung burier, incl, scoury dung.
Heliocopris faunus	Semi-dry tropic to semi-arid	Namibia – S. Africa	Sandy loams, loam; grass, shrub and pasture. Excellent sp., easier to breed than *H. andersoni*.
Heliocopris neptunus	Sub tropics	Mozambique, Zimbabwe, S. Africa	Loam to heavy loam. Not as widespread or abundant as *H. faunus*.
Heliocopris hamadryas	Wet tropics to winter-rainfall	Somalia – S. Africa Nigeria/Cameroon	Loams/ volcanic soils. Extremely adaptive sp. (geography/climate). Phenomenal dung burial.
Heliocopris bucephalus	Wet tropics	India – Sri Lanka – SE Asia – S. China	Loams, well-drained sandy clay. Pastures, forest edge. 1000- >2000 rainfall.
Kheper lamarcki	Warm temperate	Equatorial Africa, S. Africa	Sandy loam, woodland-grassland. Efficient dung removal, prefers horse dung, uses bovine dung.
Kheper nigroaeneus	Sub tropic, tropic	Ethiopia – Kenya - S. Africa	Sandy laom, loam. Woodlands to rangelands. Very efficient and fast ball-roller.
Scarabaeus laticollis	Temperate – warm temp.	West Mediterranean Sicily, Morocco	Sandy loam, loam. Grassland, pasture. Sea-shores to subalpine pastures. First to appear after snow melt. Active at low temps.
Pachylomera femoralis	Humid to dry tropics	Subsahara to S. Africa	Sand to heavy loam. Woodland to pasture. A phenomenally fast ball roller.
Circellium bacchus	Temperate, even rainfall	Southern coast of S. Africa	Light to heavy loam; shrubland ot pasture. Slow moving, aggregating ball roller. Flightless.
Sisyphus costatus	Humid tropics	Ethiopia – S. Africa	Sandy loam, loam; woodland to pasture. Can be numerous on bovine dung. Effective ball roller.
Sisyhpus crispatus	Wet tropics – sub tropics	Ethiopia – S. Africa	Sandy loam, loam; woodland to pasture. Can be numerous on bovine dung.
Sisyphus schaefferi	Temperate	W - central Europe, Medit. to China.	Loam, grassland, pasture. Widespread northern sp., very efficient in early spring on runny dung.
Neosisyphus rugosus	Sub tropics	South of Zambezi River	Loams; shrubland to pasture. Good dung removal.
Neosisyphus fortuitus	Sub tropics, tropics	Tanz. – Cameroon; southern Africa	Loam, woodland to pasture. Excellent dung disposal qualities.
Allogymnopleurus thalassinus	Hot dry tropics to warm temp.	Tanzania to S. Africa	Lightly timbered to pasture. Spectacularly efficient ball roller.

DR ADRIAN DAVIS

Adrian was a member of the CSIRO Dung Beetle project team in South Africa. He was based in Cape Town from 1978 to 1980, and in Pretoria from 1971 to 1978 and 1980 to 1986. He was involved in extensive dung beetle survey trips throughout Africa, and was curator of the CSIRO dung beetle collection in Pretoria. Adrian is still actively involved in dung beetle research, and his main interests are the historical origins of spatial patterns in dung beetles from biogeographical down to community scales of organization.

Adrian provided the following comments on selection of further species for introduction into Australia:

"The programme for the introduction of dung beetles from Africa was curtailed before the "minifaunas" envisaged by Dr Bornemissza could be constructed in all cattle-producing areas of Australia. I believe that further introductions should be made to complete this task thereby providing increased recycling of the nutrients trapped in cattle dung and more effective control of dung-breeding flies.

Recent analyses of trophic associations indicate that many Copris, Onitis, Euoniticellus *and* Neosysiphus *are primarily associated with cattle dung. I suggest that functional units comprising species from these four genera should be built up into a mosaic of minifaunas across the cattle producing areas of Australia. In reality this will result not in a clear-cut mosaic but in a series of overlapping distributions, much as is observed in Africa.*

Computer predictions of potential Australian distributions will identify species with the potential to fill gaps between the distribution centres of introduced species that have already established. Selection of each climatically suitable minifauna should also be made according to the primary soil associations of the species available. I believe most cattle-producing areas of Australia lie on finer-grained soils, so the list below mainly comprises specialists on finer-grained soils or soil generalists.

I believe that priority for introduction should be given to species associated with tropical and warm temperate regions since high levels of dung removal are recorded in comparable regions in Africa. In more temperate regions of Africa, particularly cooler winter-rainfall areas, levels of dung removal are much lower, and predatory dung beetles could be given serious consideration for introduction into Australia to augment control of dung-breeding flies."

ADRIAN DAVIS' SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Copris laoides	Dry upland	North Namibia	Large, fast burier. Sand/sandy loam
Copris denticulatus	Moist lowland	Southeast Africa	Large, fast burier. Clay/sandy loam
Copris integer	Moist highland	East Africa	Large, fast burier. Sandy loam
Copris subsidens	Dry upland	North Namibia	Small, fast burier. Sand/sandy loam.
Copris amyntor	Dry lowland	Southeast Africa	Small, fast burier. Clay/sandy loam.
Copris evanidus	Dry lowland	South to East Africa	Small, fast burier. Sandy loam/sand
Copris obesus	Moist upland	South to East Africa	Small, fast burier. Clay/sandy loam
Onitis uncinatus	Dry lowland	South to East Africa	Large, fast burier. Clay/sandy loam

ADRIAN DAVIS' SPECIES FOR FUTURE INTRODUCTION (ctd)

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onitis reichei	Moist lowland/ upland	South to East Africa	Large, slow burier. Sand/sandy loam
Onitis autumnalis	Upland (autumn)	East Zimbabwe	Large, slow burier. Sandy loam
Onitis anthrancinus	Moist upland	East Africa	Large, slow burier. Sandy loam
Euoniticellus triangulatus	Moist lowland/ upland	South to East Africa	Small, slow burier. Sand/sandy loam
Neosisyphus tibialis	Moist highland	East Africa	Small, ball roller. Clay/sandy loam/sand
Catharsius philus	Dry lowland	Southeast Africa	Large, fast burier. Clay/sandy loam
Catharsius furcillatus	Dry upland	East Africa	Large, fast burier. Sand/sandy loam
Heliocopris faunus	Dry lowland/ upland	Southern Africa	Large, fast burier. Sand/sandy loam
Heliocopris neptunus	Dry lowland/ upland	Southeast Africa	Large, fast burier. Clay/sandy loam
Heliocopris hamadryas	Moist upland	Much of Africa	Large, fast burier. Sand/sandy loam
Heliocopris hermes	Moist upland	East Africa	Large, fast burier. Sand/sandy loam
Kheper nigroaeneus	Dry lowland (woods)	Southeast Africa	Large, ball roller. Clay/sandy loam/sand
Gymnopleurus sericatus	Arid lowlands	Southwest Africa	Small, ball roller. Clay/sandy loam
Copris orion ssp. australis	Coastal	East South Africa	Small, fast burier. Sand
Copris puncticollis	Coastal	Southeast Africa	Small, fast burier. Sand
Onitis deceptor	Lowland/upland	Southern Africa	Large, fast burier. Sand
Catharsius tricornutus	Moist lowland/ upland	Southeast Africa	Large, fast burier. Sand

DR BERNARD DOUBE

Bernard was part of the CSIRO Dung Beetle Project team. He was based in Rockhampton from 1977, and in south Africa from 1980 to 1987. Bernard's research centred on selecting and testing dung beetle species for the biological control of buffalo fly. He is now the principal of Dung Beetle Solutions Australia, based in South Australia.

Bernard provided the following comments about selection of dung beetle species:

"For future introductions we need to consider the capacity of dung beetles to sequester carbon in the sub-soil. Deep tunneling species should be preferentially selected.

There are few good species for the sandy regions of southern Australia. For example, Bubas bison *does not prosper in deep sand. Sand-loving species are required, especially for WA. The major seasonal gaps are for species active in late summer-autumn and in spring.*

Below are my thoughts for species for the Fleurieu Peninsula. The list for other regions of southern Australia would be similar, but priority species would change in relation to whether the climate was warmer or cooler, and in relation to soil type. For example Bubas bubalus *is likely to be a top species in regions that are a bit too cool for* Bubas bison *to prosper. A cold-adapted subspecies of* Bubas bison *would be very desirable, if it exists. I have identified five groups of candidate beetles:*

1. *introduced species present in Australia but not yet established on the Fleurieu Peninsula (*Euoniticellus africanus, E. pallipes, Onitis caffer, Geotrupes spiniger, Copris hispanus*)*
2. *native species present in Australia but not yet established on the Fleurieu Peninsula (*Onthophagus ferox, Onthophagus granulatus*)*
3. *introduced and native species present on the Fleurieu Peninsula and possibly in need of redistribution (*Onthophagus binodis, Bubas bison, *and possibly* Onitis aygulus, Onthophagus pentacanthus, Onthophagus mniszechi*)*
4. *species available from southern Europe and southern Africa and not yet introduced to Australia (see table below)*
5. *species introduced and established in New Zealand (*Copris incertus*)*

As to how they might be introduced, it will vary with the species. I suspect that optimal success with Bubas *and* Onitis *species will be achieved through introducing 3rd instar larvae in their faecal shells to quarantine facilities in Australia."*

BERNARD DOUBE'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onthophagus vacca	Temperate and Mediterranean	Europe	Has a difficult adult reproductive diapause
Bubas bubalus	Mediterranean	Europe	Spring breeding
Euoniticellus cameloides	Winter rainfall	South Africa	Recommended by ALV Davis
Copris lunaris	Temperate	Europe	Distribution complementary to *Copris hispanus*
Onthophagus lemur	Temperate and Mediterranean	Europe	Abundant in southern France. Dung preference to be checked
Scarabaeus laticollis	Mediterranean	Europe	Spring breeding. Clay soils
Sisyphus schaefferi	Mediterranean	Europe, Asia	Spring-summer breeding. Clay soils
Copris incertus	Temperate	Mexico	Introduced to NZ from Mexico, via Western Samoa in 1956
Onitis deceptor	Subtropics	Southern Africa	For sandy regions in northern Australia

DR PENNY EDWARDS

Penny worked in the CSIRO Dung Beetle Project, and was based in South Africa from 1980 to 1985, and in Canberra until 1987. Her main role was to investigate dormancy problems which hindered the rearing of some high priority species. She also investigated the effect of seasonal changes in dung quality on the survival and breeding success of dung beetles and dung-breeding pest flies.

Penny's views on future dung beetle activities have largely been incorporated elsewhere in this review, but in summary:

"Future redistribution work should concentrate on the species identified in this review as being the most suitable, and careful attention should be given to the climatic suitability of areas selected for introduction of these species.

The prospect of future introductions is exciting, and it is clear we have a wealth of species to chose from. The next step should possibly be to discuss the logistical and quarantine issues to enable a financial estimate to be made of the likely costs of further introductions.

The more evidence we can assemble, in the form of up to date information on geographic distributions and seasonal activity, the stronger would be any case for more introductions. Quantification of the economic and environmental benefits of dung beetle activity would further strengthen such a case.

My list of desirable species was drawn up in 1985. It was directed towards buffalo fly control, and includes fast acting species, particularly those that can tolerate heavier soils."

PENNY EDWARDS' SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onitis uncinatus	Summer rainfall, subtropics	Southern Africa	Rapid dung burial. Tolerates heavier soils.
Garreta nitens	Summer rainfall, subtropics	Southern Africa	Day active ball-roller. Tolerates heavier soils than many other ball-rollers. "Gorgeous beetle"
Copris fallaciosus	Summer rainfall, subtropics	Southern Africa	Rapid dung burial. Can tolerate heavier soils than *C. elphenor.*
Kheper nigroaeneus	Summer rainfall, subtropics	Southern Africa	Can achieve spectacular levels of activity. Tolerates wide range of soil and dung types. Cannot be bred without adult female.
Catharsius tricornutus	Summer rainfall, subtropics	Southern Africa	Sandier soils.
Heliocopris neptunus	Summer rainfall, subtropics	Southern Africa	Heavier soils.
Chironitis sp. A	Summer rainfall, subtropics	Southern Africa	Active in late autumn and early winter.

JOHN FEEHAN

John worked in the CSIRO Dung Beetle Project from 1965 to 1991. He was based in Canberra, and played a pivotal role in mass rearing, release and redistribution of the introduced species. Since 1993 he has operated his own very successful dung beetle redistribution company Soilcam.

John provided the following comments on present and future dung beetle activities in Australia:

"To date, Soilcam has redistributed over 3,400 colonies of 18 different species of dung beetles. I believe it is very important that starter colonies are given the best opportunity for establishment. We use a CSIRO climate matching program [CLIMEX] to select areas suitable for beetle relocations. Female beetles are checked for egg development, and colonies are only sent when at least 80% of females have developed eggs. All colonies reach their destination within 12 -15 hours.

I consider another ten years is required to complete the redistribution of species already established in Australia.

In the meantime I believe we should be working towards the introduction of additional species. In many locations there is a gap in dung beetle activity in early spring. While this may be difficult to fill, we should endeavour to identify suitable species from those available overseas. There also appears to be a gap in activity in winter-rainfall zones after Onthophagus binodis *stops activity in April and* Bubas bison *commences in May/June.*

In my opinion, many of the species that failed in quarantine during the original CSIRO introduction program could now be successfully reared. At the time, we were handling many species concurrently, often with only limited information on their biology and life cycles. We now know a lot more about the requirements of many of these species, and could tailor the rearing procedures accordingly.

I feel that a good species with which to start this process would be Bubas bubalus*. I have seen it working in France in early spring. During the CSIRO Dung Beetle project we reared it from eggs sent to Canberra by Alan Kirk, but the few adults produced failed to reproduce. I am confident, based on our experience and improved knowledge and techniques, that if we received a good number of eggs we could now rear it successfully."*

JOHN FEEHAN'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Bubas bubalus	Temperate	Central and northern Spain, southern France	Good activity, including early spring.

GRANT FLANAGAN

Grant Flanagan was a member of the CSIRO Dung Beetle Project team, and was based in South Africa from 1979 to 1983. He currently lives on Kangaroo Island SA, where he is involved in monitoring and redistributing dung beetles.

Grant offered these comments:

"I believe a more rigorous approach to release of dung beetles is required. On Kangaroo Island we have seen quite strong site effects with Geotrupes spiniger, *and this affects both larval survival and adult emergence. It seems that some sites are much more favorable than others and identification of these would greatly enhance establishment. Confinement and management of adults in the early stages of releases should also be encouraged. Careful cattle management, particularly in relation to application of internal and external parasiticides, is essential while attempting to establish new or redistributed species.*

We are seeing considerable impact of dung beetle activity on the soil profile in areas afflicted by non wetting sands. Bubas bison *in particular is moving the clays to the surface which must be helping this issue. Perhaps this is something that could be explored further.*

We have released Geotrupes spiniger *on Kangaroo Island, and will probably introduce the winter-rainfall strain of* Onitis caffer *next. With regard to new introductions, spring and autumn active species are required in this region. I would like to see evidence that the cold-strain of* Onthophagus gazella *is suited to this region, before too much is invested in it."*

GRANT FLANAGAN'S SPECIES FOR FUTURE INTRODUCTION

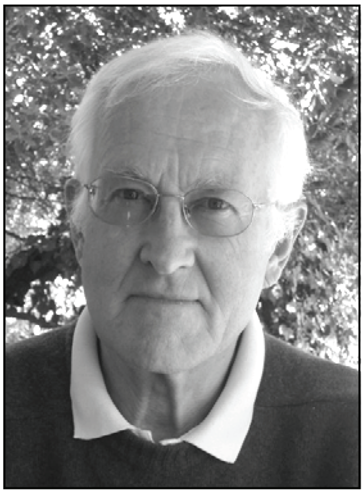
SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Sisyphus seminulum	Subtropical and tropical, summer rainfall	Southern Africa	Attains massive numbers. Attacks the edge of dung pads, therefore good for buffalo fly control.

DR ALAN KIRK

Alan was a member of the CSIRO Dung Beetle Project team. He was based in Montpellier, France from 1977 to 1984. His main activities were (i) dung beetle surveys, (ii) selecting species suitable for Australia, (iii) developing rearing methods and (iv) collecting and sending beetles to the CSIRO South African laboratory or direct to Canberra.

Alan provided the following thoughts on possible future introductions from the Iberian Peninsula:

"I have always thought that Onitis belial, Onitis ion *and* Scarabeus sacer *(from the Iberian Peninsula) would be useful additions to the Australian fauna. They are all capable of putting away a lot of dung in spring, early summer and early autumn. They are most abundant in open non-forested, very warm areas of Andalusia. The climate there is dry with periodic rain events, somewhat similar to some inland areas of South Australia.*



I succeeded in rearing both Onitis *species, but* O. belial *was ponderous and difficult to keep under confined rearing conditions. If these species can still be found, I believe they would be worth trying. If I had to choose one I think* Onitis ion *would be the most suitable for intensive rearing and release."*

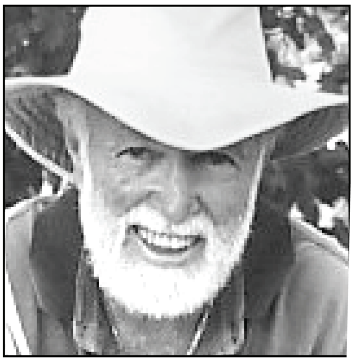
ALAN KIRK'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onitis belial	Mediterranean	Spain, Portugal	Abundant in open, non-forested areas. Active spring - autumn.
Onitis ion	Mediterranean	Spain, Portugal	Abundant in open, non-forested areas. Active spring - autumn.
Scarabeus sacer	Mediterranean	Spain, Portugal	Abundant in open, non-forested areas. Active spring - autumn.

DR ANGUS MACQUEEN

Angus (Gus) Macqueen was a member of the CSIRO Dung Beetle Project team. He was based in Rockhampton from 1974 to 1988 where he studied the impact of introduced dung beetles on survival of buffalo fly. He traveled though Kenya in 1973 while on route to take up his position in Rockhampton. While in Kenya he collected three species of dung beetles for the CSIRO unit in Pretoria. In 1983 he spent several months in South Africa with Bernard Doube's group, comparing the impact of the dung fauna on buffalo fly survival in South Africa with that in Australia.

Gus has offered some suggestions regarding future dung beetle releases:



"When planning the release of a new species, I feel it is essential to undertake the most careful climate matching between donor and receptor areas. This is so much more accurate and refined these days than it was in the past. Consideration should also be given to the current shifting patterns of rainfall in Australia. I think, for example, that some of the Onitis *species released in central Qld may have failed in the early 1980s because that region then was moving to a different summer rainfall pattern with fewer, often sporadic, falls, with long dry periods in between - inimical to beetle establishment. Meteorologists and climatologists now have a better understanding of how rainfall patterns are likely to change in future, with implications for the release of any new species.*

I would like to see all initial releases made using trained personnel, rather than sending beetles direct to farmers. This should be factored in as part of the cost of introducing a new species. Protection from bird attack is often necessary, at least in Qld where crows and ibis can wreak havoc with dung beetles. For the new species, it may be feasible to use 'nursery' regions within zones of projected adequate rainfall in which they might establish and from where they could be harvested later. It may slow their initial spread, but it would increase the probability of establishment in Australia. And of course we need to prevent new beetles initially coming into contact with dung from cattle treated with toxic anthelmintics, something we didn't have to worry about in earlier times.

I recall long ago George Bornemissza wrote about the decline in distribution of some dung beetle species in Europe in areas where cattle were increasingly being kept indoors. This could be something to keep in mind if new species were to be collected from those parts of Europe"

GUS MACQUEEN'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onthophagus quinquedens	Tropical, summer rainfall	Includes Mozam-bique to Kenya	For tropical Australia. A large *Onthophagus.*
Onthophagus vacca	Temperate, winter rainfall	Central and northern Europe	For southern Australia.
Onthophagus nuchicornis	Temperate, winter rainfall	Central and northern Europe	For southern Australia. Accidentally intro-duced to eastern Canada and later arrived in the west (British Columbia, Alberta) where it is abundant in spring/early summer. Good dung burial and shredding noted.

KAREN OLSEN (PASCHALIDIS)

Karen was a member of the CSIRO Dung Beetle Project team. She was based in South Africa between 1972 and 1975, where she completed a Master's thesis on the *Sisyphus* ball rollers. From 1976 to 1980 she was based in Athens, Greece, and was involved in the selection of European dung beetle species for Australia, and the collection and shipment of these either to the CSIRO laboratory in Pretoria, or direct to Canberra.

Karen provided the following comments on the selection of further species for Australia:

"In South Africa the two Sisyphus *species that stood out were* S. spinipes *and* S. rubrus. *They were the most numerous and most widespread species of that genus. These two species were selected for Australia, and are now well established here. The other* Sisyphus *species in South Africa either occurred in a more restricted habitat or had a more restricted seasonal occurrence. Their distributions usually overlapped with the two major species. Thus, unless we were looking to fill a particular niche, I think the best* Sisyphus *species are already in Australia."*

With regards to other genera, nearly all the species that stood out as suitable candidates for Australia were either imported, or at least were given serious consideration.

I recall being impressed by the activity of Onthophagus opacicollis *and* O. vacca *in Greece, so these two species could be worth reconsidering for future introduction. In South Africa,* Allogymnopleurus thalassinus *was an impressive ball-rolling species.*

Hibernation/aestivation in some species caused problems with rearing. If more is known now about overcoming these problems, maybe other species, previously thought too difficult to rear, could be reconsidered. I believe some of the Copris *species fell into this category."*

KAREN OLSEN'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Onthophagus opacicollis	Mediterranean	Europe	In Greece, active in spring, early summer, autumn and winter, especially in drier areas
Onthophagus vacca	Temperate and Mediterranean	Europe	In Greece, active in spring and summer but appears to prefer a wetter climate
Allogymnopleurus thalassinus	Tropics to warm temperate	Southern Africa	Impressive levels of activity, particularly during late spring/early summer

DR JAMES RIDSDILL-SMITH

James was a member of the CSIRO Dung Beetle Project team from 1977 to 1989. He was based in Perth WA, but travelled extensively to South Africa, Spain, Portugal and France to study dung beetles in the field. His main research centred on controlling bush fly in WA, and in studying the effects of dung beetle density on beetle reproduction and its impact on bush fly numbers.

James has provided the following comments on maximising the benefits of dung beetles and on possible future activities:

"*The CSIRO program to introduce dung beetles had aims to control buffalo fly, bush fly, sheep parasites, to bury dung to improve soil fertility, water infiltration and recycle organic matter. However each beetle species affects these factors in different ways.*

In south-western Australia John Matthiessen and I focussed on the impact of introduced dung beetles on the bush fly problem. We showed that introduced dung beetles can control bush flies in the field. The greatest impact on bush flies occurs when dung beetles are active in spring (Ridsdill-Smith and Matthiessen 1984).

A study of dung beetles in Spain showed that adaptation to climate is greater than to soil or dung type (Kirk and Ridsdill-Smith 1986). The species adapted to winter rainfall climates that bury most dung in Spain in spring are Copris hispanus *and* Bubas bison, *both of which are large species with a univoltine life cycle (Ridsdill-Smith and Kirk 1985). Large beetles that bury dung quickly have a greater impact on bush fly mortality than smaller dung beetle species (Ridsdill-Smith 1993). Both* C. hispanus *and* B. bison *have been released in WA, and are established.*

I feel we shouldn't consider further introductions at present but should put some more effort into looking at what has worked and what has not, and see if we can improve the way the beetles are functioning. Future work in WA should evaluate the impact of C. hispanus *and* B. bison *on bush fly populations, and these species should be systematically redistributed to areas where they are not present currently. This can be done by cropping and redistributing, by collecting and mass rearing for re-release, or possibly by going back to southern Europe to find strains better adapted to areas where currently in Australia they are not established.*

I see limited value in continuing to crop and redistribute the small summer active opportunist species ("r selected") that are quite capable of spreading naturally.

I would like to see more work looking at the interaction between introduced and native dung beetles to determine if introduced beetles are having any impact on native beetles in undisturbed habitats."

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DR MARINA TYNDALE BISCOE

Marina was part of the CSIRO Dung Beetle Project from 1974 to 1995. Her research included studying the impact of dung beetles on bush fly populations, developing rearing methods for dung beetle species with maternal care, and developing physiological age grading techniques for dung beetles. Marina traveled to Mexico in 1981, to Spain in 1986 and to Uruguay in 1991 to study dung beetles in the field. Marina's book "Common Dung Beetles in Pastures of South-Eastern Australia" has been a key resource since its publication in 1990.

Marina provided the following suggestions on gaps which could be targeted in the future:

"I have recognized several gaps in dung beetle activity in Australia which would benefit from being filled. One such gap (in relation to fly control) is the flood irrigated pasture system, where water inundation for several hours or days drowns the larvae of beetles, while flies can develop between these flood episodes. Such a system would require an effective predator of fly larvae, such as a staphylinid beetle.

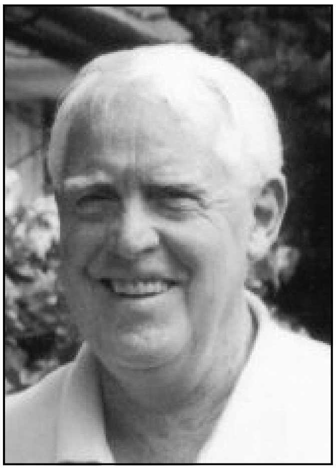
Another gap which is becoming more obvious as the drought continues is for species able to survive and work in dry conditions. This is very obvious here around Braidwood NSW, which has had a good coverage of beetle species but there has been little evidence of beetle activity during these last few summers. In January I went looking for dung beetles, and only found a few during several hours of searching.

And of course, there is the winter gap with no beetle activity at all."

DR KEITH WARDHAUGH

Keith was involved in the CSIRO Dung Beetle Project, and was based in Spain from 1984 to 1987. His research centred on dormancy problems encountered in rearing some key species, and he was instrumental in selecting and importing species from Spain for bush fly control in WA. He led a program in 1990 to 1992 to bring adult dung beetles from Spain through the high quarantine facility (AAHL) in Geelong, for ultimate release in WA.

Keith has provided the following suggestions about future dung beetle activities:



"The current review can be used to identify the main gaps in space and time. I suggest the next stage would be to canvass the livestock industries to support:

1. *further cropping and redistribution, based on the recommendations in this review;*
2. *a second Double Helix (or schools) program to provide updated distribution data to support (1), and*
3. *the introduction of some key new species.*

In considering importation of new species, we should pay particular attention to the security requirements of the airlines that would be involved in the transit of such beetles. With terrorism security checks now in place, moving beetles around in sealed boxes is likely to be a very much more hazardous exercise than in the past.

A new introduction program will be very expensive but it is possible that it could be made considerably cheaper if we were not required to use a high security quarantine facility. It would also be much more successful if we could devise a less harmful quarantine procedure and/or convince AQIS (Australian Quarantine and Inspection Service) that the need for dipping dung beetle eggs in formalin is unnecessary. I would suggest therefore that we:

1. *support a M.Sc/Ph.D student to do a review of recent developments in surface sterilisation procedures, followed by a laboratory examination of potential methodologies;*
2. *discuss the beetle import procedure that was submitted to AQIS for the AAHL Dung Beetle project to see what, if any, simplifications AQIS might accept. It is possible for example that we may be able to demonstrate to them:*

    a) that incoming beetles need only to be held in a secure laboratory, which would make the whole exercise a lot cheaper;

    b) that a beetle colony that is held in laboratory isolation for say two full generations post-importation, is unlikely to harbour viruses such as Foot and Mouth Disease, African Swine Fever, Bird Flu etc. because no intermediate host is available. In such circumstances it would not be necessary for formalin treatment. Whilst in captivity, these insects could be fed on dung from moxidectin-treated cattle which would also ensure that they were free of nematode infections."

KEITH WARDHAUGH'S SPECIES FOR FUTURE INTRODUCTION

SPECIES	CLIMATE	DISTRIBUTION	COMMENTS
Bubas bubalus	Temperate	Central and northern Spain, southern France	A frenetic dung disperser, frequently seen at >100 beetles per pad. Rearing is difficult, but can be done.

DR JANE WRIGHT

Jane was a member of the CSIRO Dung beetle project team, and was based in South Africa from 1984 to 1986, and then Brisbane until 1988. Her research focussed on the predatory insects that come to dung, with the aim of selecting the most suitable predators of buffalo fly for potential introduction to complement the activity of dung-burying dung beetles in Queensland. Although Jane moved on to other research areas in CSIRO, and is currently in senior management within CSIRO Entomology, she has retained an ongoing interest in dung beetles and has been CSIRO's representative at various dung beetle forums over the years.

Jane provided these comments about future directions:

"This report represents an important step forward in clarifying where the dung beetles have got to and what should happen from this point.

Now that so much effort has been put into collecting and collating so much important data for this project, it is critical for any future work to archive it appropriately. CSIRO is the logical place for this and I will facilitate the process.

Now, more than ever before, any new research project (such as further introductions) has to be rigorously justified both scientifically and fiscally and supported by the stakeholders. Therefore, I applaud the recommendations from this report, particularly the measured step-by-step approach: fill the gaps in knowledge, undertake appropriate re-distributions, mount the case for future introductions and finally, plan the program to maximise establishment while minimising time and costs."

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