ERMA New Zealand

Evaluation and Review Report

Application to release 11 species of dung beetle to overcome the many adverse effects caused by animal dung in New Zealand pastures

Application Code: ERMA200599

Prepared for the Environmental Risk Management Authority

1. Executive Summary

- A consortium of farmers, researchers and other interested parties has applied to the Environmental Risk Management Authority (the Authority) to release eleven species of dung beetle.

- This evaluation and review report is written by the Agency, a body which supports the Authority. It provides an overview of the beneficial and adverse effects of releasing these eleven species.

- The Agency has found that there are multiple non-negligible benefits to releasing these species.

- There are environmental and human health benefits from enhanced water and soil quality and economic benefits from an increase in farm productivity by the actions of the beetles.

- Given the obligate nature of true dung beetles in regard to what they feed on, one of the beetles in the application has been suggested to be declined. Of the proposed dung beetles, *Geotrupes spiniger* is in a Family that are known to utilise other food sources besides herbivore dung and thus poses a non-negligible risk to the native Scarab beetles.

- Of the remaining ten species no adverse effects were found to be significant given that the recommended species will be restricted to pastureland and are reliant on large herbivore dung.

- The Agency is therefore recommending approval of all the dung beetles in this application to import for release except *Geotrupes spiniger*.

2. Context

Purpose of the application

2.1 It is estimated that there is 10 million cattle and over 30 million sheep being farmed in New Zealand. Over the last 150 years the New Zealand landscape has been greatly modified with significant portion of its forest cleared to establish ryegrass and clover pastures for these animals.

2.2 However, in the establishment of New Zealand’s pastures little thought was given to the significance of biodiversity in creating a sustainable system. A prime example is the beetles that naturally process the dung of herbivores have not been considered seriously for introduction until now. There is little doubt the waste products of cattle and sheep have negative impacts on the New Zealand environment and that this impact is a result of the low biodiversity of our pastures. Having to deal with the dung on the ground and the consequences of its run off is a cost to both farmers and the tax payer.

2.3 To address this problematic lack of biodiversity an application has been made to release eleven species of beetle that rely on herbivore dung for their survival. All eleven species were chosen because of their preferences for the different climate and soil variables found in New Zealand and their activity at different times of the year (Edwards, 2010). All are known to utilise large herbivore dung and live specifically in open pasture.

2.4 In the past there have been four attempts to introduce dung beetle species into New Zealand before the HSNO Act came into force. Three of the species formed limited but never-the-less self-sustaining populations in Northland. While their populations may be limited in extent there are farmers that testify that these dung beetles play a substantial role in improving the overall soil and pasture health on their farms.

2.5 The applicant, a consortium of farmers, researchers and interested parties, believe these new species of dung beetle will help to:

- Improve soil health, structure, and fertility;
- Improve water infiltration and reduced flooding;
- Reduce nutrient runoff and waterway pollution;
- Reduce greenhouse gas emissions from dung and urine;
- Increase biomass and activity of earthworms;
- Increase availability and yield of forage plants;
- Reduce re-infection of livestock by parasitic worms;
- Reduce use of animal drenches; and
- Improve sustainability of pastoral production.

Organism Description

2.6 There are more than 5,000 species of beetles that are referred to as dung beetle (Monaghan et al, 2007). They are associated with the decomposition of animal manure, and can be found on all continents except Antarctica. Dung beetles feed partly or exclusively on faeces.

2.7 The beetles applied for are:

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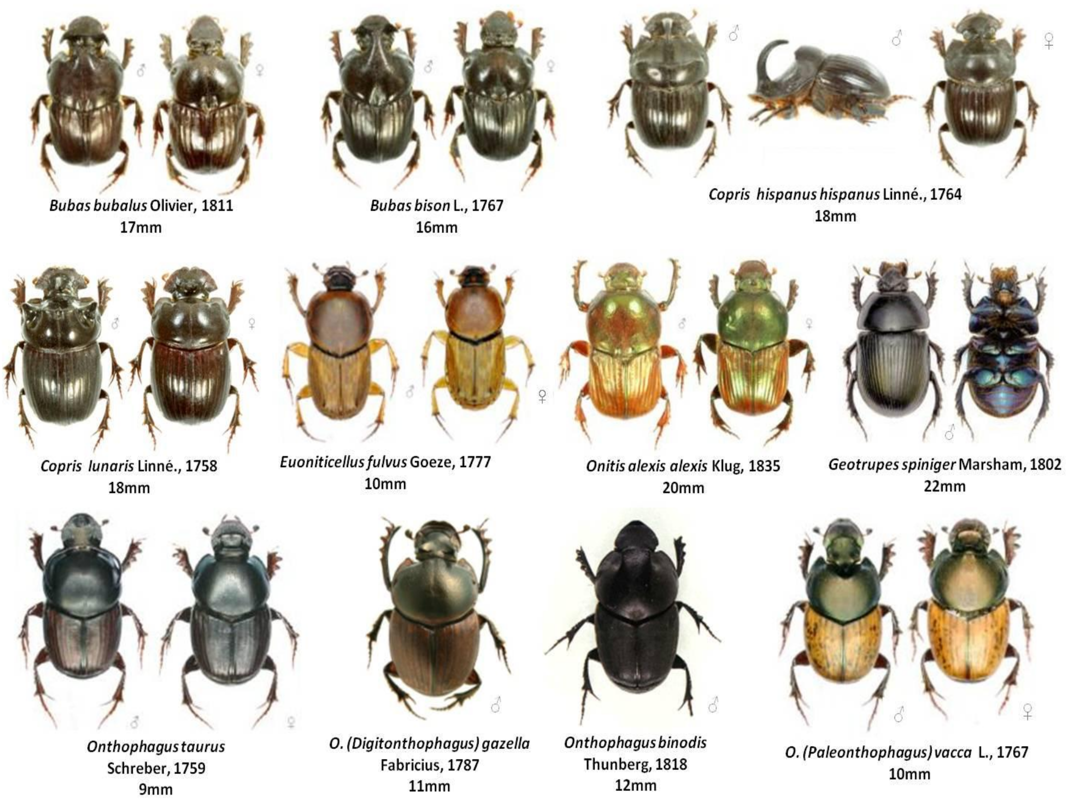

2.8 The beetles referred to as dung beetles are a functional group within the Scarabaeidae, that is, they are a subset of taxa within a larger taxonomic unit. They are separated from those other taxa by their dependence on dung as their principal food source.

2.9 Not all Scarabaeidae are functional dung beetles but rather detritivores[1]. Dung is a short-lived food source and dung beetles have evolved specialised niches and behaviour to maximise the food that is available to them (Jacob et al, 2008).

2.10 One group of dung beetles are those that have evolved to use the dung of large herbivores that graze the savannah of Africa and steppes and plains of Eurasia. It would be easy to leap to the conclusion that Africa and Eurasia represent different

[1] feeders of decomposing organic matter

geographical and therefore different faunal regions so that the beetles from these two areas should be treated differently.

2.11 However, biologically these geographical areas have much more in common than current distribution of mammals would indicate. For example the work of Visera et al (2006) has shown that in Spain, during the Pliocene- Pleistocene period, large mammalian herbivores from Europe, Asia and Africa were all present at the excavation site indicating a much broader and equitable distribution of mammal species, and therefore their associated fauna, than observed today.

2.12 The group of dung beetles in this application co-evolved with Afro-Eurasian herbivores and evolved mechanisms to seek out the habitat where these large mammals were likely to be found, that is, open grasslands. They also evolved the strategy of moving towards light and away from wooded or forested habitats that did not contain their preferred food source.

2.13 Dung beetles have a powerful sense of smell and are attracted to fresh dung and as the dung ages it becomes less attractive to beetles (Flechtmann et al, 2009). Beetles must locate dung quickly before its quality deteriorates and is colonised by other dung users, especially insects and fungi.

2.14 Dung represents ephemeral islands of resource in the life-cycle of this group of dung beetles. If there is no herbivore dung present in the environment then there will not be any dung beetles.

2.15 The pasture system that has developed in Europe represents a modification of natural grasslands and it is this modified grassland that has been transplanted to New Zealand, although in a much simpler form. The applicant proposes to introduce 11 species that have evolved with the herbivores of the savannah and steppes of Africa and Eurasia and are now found in association with domestic herbivores.

2.16 It is at this time, for the purposes of the review, we have considered those Scarabaeidae that are obligate exploiters of dung 'true' dung beetles.

2.17 With this in mind, the Agency does not consider that *Geotrupes spiniger* a 'true' dung beetle, but a 'dor' beetle in the family Geotrupidae. The other 10 species in this application are in the Scarabaeidae family. For the purpose of this advice the classification in Skidmore (1991) has been applied. Therefore, *Geotrupes spiniger* has been excluded from the group and assessed separately.

2.18 All the Scarabaeidae beetles in the application collect and tunnel immediately below the dung pat to form the nest in which they lay their eggs and raise their larvae. Although these species all occur in broadly the same habitat, open grasslands, they differ in body size, the amount of dung utilised, seasonality, daily activity period, and numbers of generations per season. It is these differing biological characteristics that enable co-existence of more than one species in dung and enhance the full use of the dung.

2.19 We note that based on the modelling conducted by Edwards (2010) many of these species will have very limited distribution in New Zealand. For example Bubas bubalus is only likely to establish around Napier, coastal Canterbury and coastal Marlborough.

2.20 It is this limitation on suitable environments for individual species that requires the release of a suite of species to ensure wide geographic establishment and subsequent good use of the available dung.

3. Minimum Standards

3.1 Any organism being assessed for release must pass the five minimum standards as stated in the Hazardous Substances and New Organisms (HSNO) Act 1996. This section should be read in conjunction with Appendix 3.

Cause any significant displacement of any native species within its natural habitat

3.2 ERMA New Zealand have assessed the information provided by the applicant, and from our own investigations, that the introductions of the species of Scarabaeidae will not cause any significant displacement of any native species within its natural habitat.

3.3 Some submitters were concerned that these new species would displace the native Scarabaeidae in the genera *Saphobius*, *Saphobiamorpha*, and a yet to be named genus which had been referred to as native dung beetles. There are 16 species in these three genera and although they can feed on dung they are not dependent on it. In general they are detritivores feeding on a wide range of decomposing matter including animal carcases within native forest.

3.4 We therefore have concluded that these New Zealand species are not functional dung beetles and therefore New Zealand has no 'true' dung beetle fauna to be displaced by the introduced species. We have also concluded that evidence supports that the Scarabaeidae species being assessed, are limited to open pasture, thus the displacement of the native Scarabaeidae beetles in their natural habitat is not expected to occur.

3.5 We are of the opinion that it is not possible that any of the species of introduced Scarabaeidae could move into the habitat occupied by the native Scarabaeidae. For this to occur:

- The beetles would need to start to prefer the dung of the mammals that have established in New Zealand forest ie, deer, goats and pigs.
- The dung of these species would have to consistently occur in densities to allow the establishment of a self-sustaining population of beetles.
- The beetles would also have to modify their reproductive behaviour as it is unlikely that they would be able to tunnel into the root mat that forms the forest floor.
- The beetles would also have to change their inherent behaviour to move away from light ie, to prefer the gloom of the forest if they are to find their new food source.

3.6 It would seem almost impossible to us that all of these changes could occur simultaneously and therefore it would be almost impossible that they could colonise native forest.

3.7 We note that some submitters are concerned that once a new species is released it will evolve and behave unexpectedly. These are two distinct concerns and need to be assessed separately.

3.8 With respect to unexpected behaviour we accept that this can and does happen. This is not the result of some inherent change within the organism but represents the establishment of novel interactions at the place that it is introduced in comparison to its home environment. Our review of the available information does not indicate that dung beetles, when introduced to a new environment, have behaved significantly differently than was expected. In this regard, we do not see that New Zealand is any more novel or special than Australia, Europe or North America where new species of dung beetle have been introduced without any observable changes in behaviour.

3.9 In regard to evolution, we have no doubt that organisms evolve. However, the information that we have reviewed does not indicate that there are any cases where newly established organisms in New Zealand have perceptively changed through evolutionary processes.

3.10 Over the past 240 years around 40,000 new species have been established in New Zealand without any observable evolutionary change. We are of the opinion that, whether you invoke gradual or punctuated equilibrium, the time scale of 240 years is far too short to witness such change. It is not possible to foretell how long a period would be needed before perceptible evolutionary changes occur but it could be hundreds, if not thousands of years.

3.11 Phylogenetically, the Scarabaeidae beetles in this application represent a group that is highly evolved to feeding and processing the dung of mammalian herbivores. As such they have very specialised mouth parts which only allow them to harvest and ingest particles below 50µm in diameter. Essentially, they feed on a slurry of nutrient rich liquid containing, amongst other things, bacteria and dead gut epithelial cells (Holter et al, 2002).

3.12 This adaptation of the mouth parts is so specialised it is difficult to see that they could readily evolve to feed on other material. This group has evolved from the less specialised detritivores (Monaghan et al, 2007), represented in New Zealand by the so called native dung beetles.

3.13 However, the assessment of *Geotrupes spiniger*, in the Geotrupidae, is different because it is not a true dung beetle but a dor beetle. This family has many detritivore that consumes a significant proportion of its diet in the form of herbivore dung.

3.14 Because *Geotrupes spiniger* is potentially a detritivore, we conclude that, in the lack of evidence to the contrary, there is a possibility that this species could compete with native Scarabaeidae beetles. This competition could conceivably result in the significant displacement of native Scarabaeidae beetles within their natural habitat. Given the uncertainty resulting from the lack of specific information we recommend that *Geotrupes spiniger* not be approved for release.

3.15 Submitters also highlighted the concern that other native habitats hosting unknown native organisms, for example high country tussock, could be adversely affected by the introduction of these Scarabaeidae beetles.

3.16 All of the Scarabaeidae beetles in this application only eat and use the dung of large introduced herbivores, and consequently can only be found where their dung is present. If there are no herbivores present then there will not be any dung and therefore there will not be any beetles. We have taken the view that land that is farmed with grazing cattle or sheep has been extensively modified by their grazing and the introduction of pasture fodder and weed species to a point where it could not be considered a truly native habitat. Thus it is very unlikely there will be any displacement of native species from its natural habitat from the introduction of these Scarabaeidae beetles.

Cause any significant deterioration of natural habitats

3.17 We have reviewed the available information on the ability of these Scarabaeidae beetles to cause significant deterioration of natural habitats. As noted above these Scarabaeidae beetles require the continuous presence of large herbivores to supply dung for their existence and the presence of herbivores in sufficient numbers to maintain a beetle population would have already significantly altered the natural habitat. We therefore conclude that Scarabaeidae beetles will not cause significant deterioration of natural habitats.

Cause any significant adverse effects on human health and safety

3.18 We have reviewed the available information and concluded that these Scarabaeidae beetles did not have the ability to cause any significant adverse effects on human health and safety.

Cause any significant adverse effects to New Zealand's inherent genetic diversity

3.19 We have reviewed the available information and concluded that these Scarabaeidae beetles could not cause any significant adverse effect to New Zealand's inherent genetic diversity. We reached this conclusion because the native Scarabaeidae beetles are not closely related to the proposed introduced species and therefore could not breed with them.

Cause disease, be parasitic, or become a vector for human, animal, or plant disease

3.20 We have reviewed the available information and concluded that these Scarabaeidae beetles could not cause disease, be parasitic, or become a vector for human, animal, or plant disease.

Are the Minimum Standards met?

3.21 In our view these Scarabaeidae beetles meet the minimum standards as stated in the HSNO Act 1996, and can be further evaluated. However, it is our view that *Geotrupes spiniger* does not meet the minimum standards and therefore should not be approved for release.

4. Benefits and Risks of the Release of the Scarabaeidae Beetles

4.1 We have assessed the potential benefits and risks of the organisms that could result from the release of the 10 species of Scarabaeidae beetles in Appendix 3.

4.2 As noted in 2.2-2.3, the benefits accrue from biological activity resulting from increased biodiversity. It is noted that submitters have highlighted that all benefits are difficult to gauge accurately, as they would be extrapolated from overseas data, not from the New Zealand pastoral environment.

Grassland organism assemblages, biodiversity and sustainability

4.3 We note that New Zealand's vegetation production system is artificial with approximately 50 plant species dominating 95% of our domesticated land area of 12.2 million ha (Taylor and Smith, 1997).

4.4 The New Zealand pasture system is the result of a concerted human effort and as stated by Brooker (2006), "The Government, farmers and seed merchants also worked hard to lay down artificial English pastures (mainly rye grass, cocksfoot and white and red clover). By 1920 about 18 million acres in New Zealand had been covered in the green swards of England." And that this green sward has been maintained largely through the application of artificial fertilisers (Brooker, 2006).

4.5 The maintenance of this pasture system is not sustainable long-term and only the clever use of biodiversity is likely to offer solutions (Heal, 2005; MacLeod and Moller, 2006). New Zealand's primary production is the result of the clever use of exotic bidiversity.

4.6 In 2.5 the benefits identified by the applicant are listed. These can be assessed individually and as such are likely to be only minor and easily dismissed. However it is our view they should be seen as an inseparable, whole benefit which is likely to occur and significant because the effects are additive and not discrete.

4.7 As noted in the Organism Description section (starting at 2.6) dung beetles are part of a bigger assemblage of organisms that constitute a grassland ecosystem. This grassland ecosystem, at various times, has been contiguous across Africa and Eurasia. These grasslands coevolved with the herbivores that grazed them and the fungi, insects, and other invertebrates that utilised the herbivore dung.

4.8 In comparison New Zealand's pastures are a human-made construct with the addition of inadvertent arrivals which, all-in-all, have created a productive but not sustainable production system (MacLeod and Moller, 2006).

4.9 The desired organisms in New Zealand's pasture system consist principally of rye grass, cocksfoot and white and red clover, honey and bumble bees for pollination, a number of earthworm species, and the production animals that graze it (mainly cattle and sheep), which were all introduced. Everything else arrived inadvertently and often its role is poorly understood.

4.10 We also understand that our pastures are not self-sustaining in that they rely on heavy input of labour and chemicals to keep them productive and to prevent them reverting to other vegetation type ie scrubland and forest.

The relationship between earthworms and dung beetles

4.11 Focussing on the soil component of the system, Martin and Charles (1979) clearly outline the benefits of earthworms to soil structure by increasing the penetration and holding capacity of water, while at the same time incorporating dung into the soil structure and increasing organic content of the soil.

4.12 The very same benefits can be attributed to dung beetles (Bang, et al 2005). It has been argued that the activities of worms and beetles could be competitive but even in the 1997 MAF consideration of the release of a dung beetle Jo Springett (AgResearch) stated "...the effect of dung beetles removing dung as a food source for earthworms is to reduce the potential earthworm food by less than 10%. It is unlikely that this would significantly decrease positive effects of earthworms on soil structure and root distribution. If dung beetles were active mainly in summer their effect on earthworms would be even less and dung removal from the soil surface during summer would be assured".

4.13 There is obviously a synergy between earthworms and dung beetles and this has been demonstrated by Doube (2006). Doube has shown that earthworm numbers and activity increase in the presence of dung beetles. However, there is equally an argument that the current New Zealand production system is working and that there is a risk of harming it by introducing new species. There is no evidence that dung beetles would harm the system so the discussion boils down to one of conservatism versus sustainability.

Control of pest species: flies and nematodes

4.14 As noted above there are a large number of insects and other invertebrates that use dung pats as a habitat and a food source. When Europeans moved their domestic herbivores to new regions eg, Australia and New Zealand, only a small part of the associated fauna was transported as well. In some cases this was deliberate but in the majority of cases it was inadvertent.

4.15 In many cases without the full dung fauna being present those species that did arrive were able to take advantage and reach pest proportions. This was the case in Australia where bush and buffalo flies became a major problem as they used the available dung to become major pests.

4.16 Between 1968 and 1992 the Australians have released 43 species of dung beetles of which 23 species have established. These releases have significantly reduced the Australian fly problem (Ridsdill-Smith and Matthiessen, 1988; Fay, et al 1990).

4.17 Although New Zealanders may not perceive the fly problem to be on the scale of Australia's it is none-the-less a problem. It also likely to increase if climate change occurs or there are incursions of new fly species from overseas.

4.18 Dealing with the dung problem before any future incursion will reduce the likelihood of an establishment. If the dung is not dealt with and establishment occurs it will need to be dealt with by chemicals which may be unsustainable. The potential use of chemicals to either eradicate or manage an establishment comes with a high social cost as was learnt during the moth eradication programmes in Auckland.

4.19 A similar argument can be made with the problem of intestinal round worms (nematodes). These parasites of herbivores live as adults in the intestinal tract of the host mammal and their eggs are released in the dung. The eggs hatch and the larval stages live as detritivores in the dung. At a particular developmental stage the immature larvae migrate to the top of the vegetation cover and wait to be eaten by a passing herbivore.

4.20 Intestinal round worms are a major problem in New Zealand. Much of the drenching and topical application of anthelmintics that occurs in New Zealand is for the control of the nematodes. Long-term this is not sustainable due to the possibility of consumer backlash to increased chemical treatments and from the nematodes developing resistance to the anthelmintics.

4.21 Strategies that have been researched to reduce reliance on anthelmintics include grazing management, vaccination, breeding for resistance, improved nutrition, biological control, and integrated controls (Eysker, 2001). Clearly dung beetles could play a role as either a biocontrol agent or in integrated pest control programme. The use of dung beetles could also provide benefits to organic farming where pests need to be managed without the use of inorganic pesticides.

4.22 A number of submitters have voiced concern in regard to the survival of intestinal round worm larvae in buried dung (Waghorn et al, 2002). In one of the experiments the researchers placed sheep dung on the surface of soil in pots and buried it in the soil in pots. They found that more nematode larvae were recovered from the buried dung than from that on the surface, and attributed it to the surface dung being exposed to unfavourable climate for the nematode larvae.

4.23 Submitters concluded that if beetles buried the dung then more nematode larvae would survive to infect stock and consequently increase disease severity. We accept the results of the experiment, but in our opinion they show the effect of humans burying dung and not the effect of beetles burying dung.

4.24 These actions are not equivalent as the humans buried intact dung pellets whereas beetles would process by mining thus aerating the dung and increasing the exposure of nematode eggs to desiccation. Moreover, by chewing the dung some of the eggs and nematode larvae would be physically destroyed. Also, by lining their tunnels with the processed dung material nematode larvae would be exposed to other predatory soil organisms and thus further reducing their numbers.

4.25 We note that the experimenters (Waghorn et al, 2002) acknowledge that they did not assess the action of beetles but in our judgement their conclusions while relevant are not conclusive.

The effect of drenches on the establishment of dung beetle

4.26 Overseas experience is that many of the anthelmintics in use are toxic to dung beetles so establishment of beetles on farms where they are used is difficult.

4.27 There is an argument that if the spread of dung beetles is limited by the use of anthelmintics then there cannot be any benefits. This may indeed be true if a short term approach is taken. However, as with other biocontrol agents, a much longer frame of reference should be taken and it may be 20, 50 or 100 years before significant benefits are seen.

4.28 This does not mean that smaller benefits will not accrue for individual farmers, as is the case in Northland now for John Pearce[2], and for organic farms where establishment will not be hampered by anthelmintics. With time, and as the benefits are shown on these individual farms there will be increasing interest in the use of dung beetles, especially with increasing demand from consumers and Government for producers to demonstrate that their production is sustainable.

[2] http://www.youtube.com/watch?v=pLwNFBtSOOU

5. Conclusion

5.1 This application is to import for release eleven exotic species of dung beetle to overcome the adverse effects caused by animal dung in New Zealand pastures. These effects include; reduced pasture for feed because of dung contamination, excess nutrient runoff and waterway pollution, increasing nuisance insect populations and a reduction in sustainability of current farm practices. The main differences between the species are climate and soil preferences. This is why more than one species is required to deal with livestock dung across the New Zealand pastoral landscape.

5.2 The Agency recommends approving the application to release 10 of the eleven proposed dung beetles. These organisms pose a negligible risk to the New Zealand environment, human health, relationship of Māori to the environment, on society and community or the market economy and the assessment shows the benefits of the organisms outweigh any risks and that the minimum standards are not triggered. Furthermore, approval of this application is not considered to be inconsistent with the principles of the Treaty of Waitangi.

5.3 One species, *Geotrupes spiniger* may trigger the HSNO Act minimum standards, by out-competing native beetles as they are not obligatory users of herbivore dung as the other 10 beetles are. With this in mind the Agency recommends declining *Geotrupes spiniger* for import into New Zealand.

5.4 The Agency has found that there are multiple non-negligible benefits to releasing these 10 species. As a collective we regard the magnitude of the benefits to be **major**, and are **highly likely** to occur, and therefore the composite benefit to be **high**.

5.5 There are significant environmental benefits from enhanced water quality and improved soil and pasture quality leading to economic benefits from an increase in farm productivity. Given that these introduced species will be restricted to pastureland and utilise only large herbivore dung, all adverse effects were considered **negligible**.

5.6 The Agency is therefore recommending approval of all the dung beetles in this application for import and release except *Geotrupes spiniger*.

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