Dung Beetles in Southern Wisconsin

Dung beetle holes in cow pie, photo by Cherrie Nolden

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Summer Conservation Camp Webinar

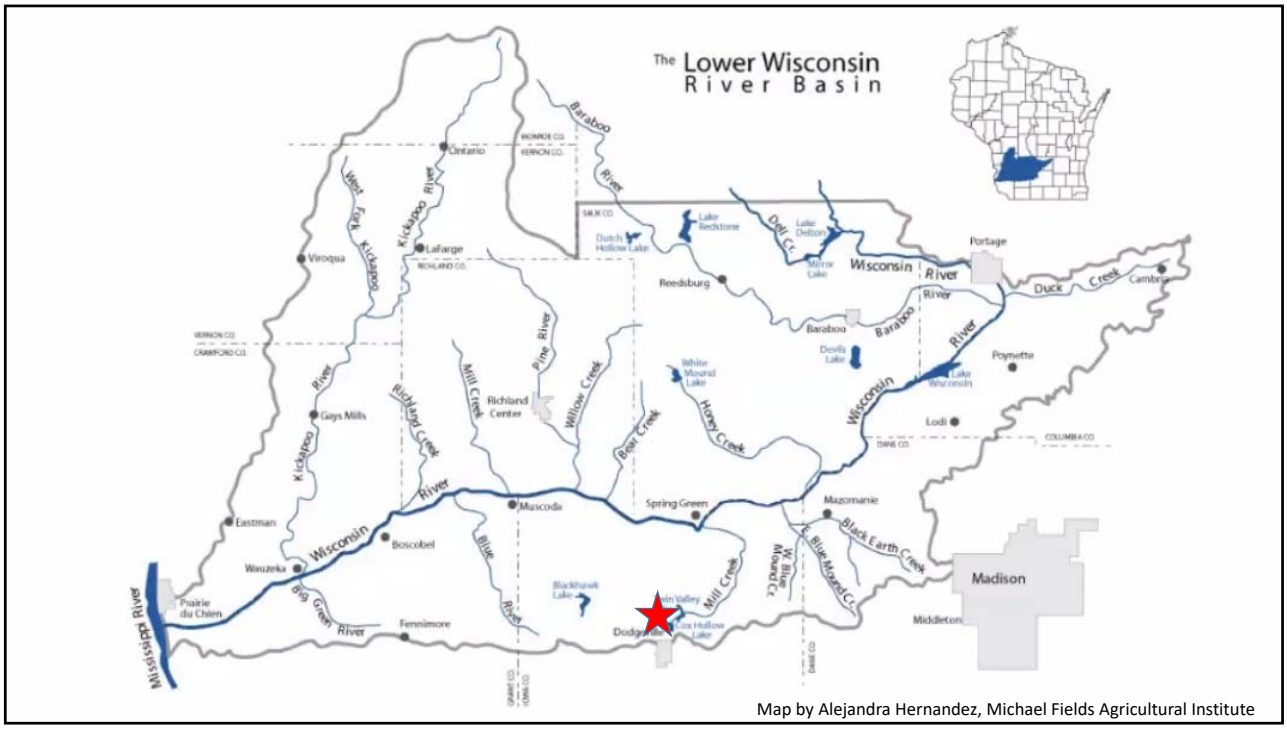
7/20/2023

Onthophagus hecate,
photo by Cherrie Nolden

Outline

- Context of place
- Why focus on dung beetles
- Other desirable manure insects
- Dung beetle life cycle
- Beetles in Wisconsin
- Benefits to livestock
- Chemical dewormer and insecticide impacts
- Benefits to the environment
- Challenges
- Summary

Photo by Cherrie Nolden; 2021 collection of species



Map by Alejandra Hernandez, Michael Fields Agricultural Institute

Our Farm System - Layout

Our Farm System





Photos by Cherrie Nolden

Our Farm System - Outreach



frontiers

Soil Energetics: A Unifying Approach to Quantify Soil Functionality

Photos by Andrew Hinrichs, 2020 Horse Pasture Walk event

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Why Dung Beetles?

Environmental and economic benefits from the services provided by dung beetles include.....

Improve soil fertility.....*nutrients in dung*
Improve soil structure.....↓*soil compaction*
Improve soil biology.....*pasture earthworms*
Increase available grazing area.....↓*forage fouling*
Increase pasture productivity.....↑*grass yield*
Improve water infiltration..... *via tunneling*
Improve water quality.....↓*surface run-off*
Reduce pests/disease.....↓*gut parasites, face flies and horn flies*
Sequester carbon.....↓*gas emissions*
Feed wildlife..... ↑*grassland bird food*

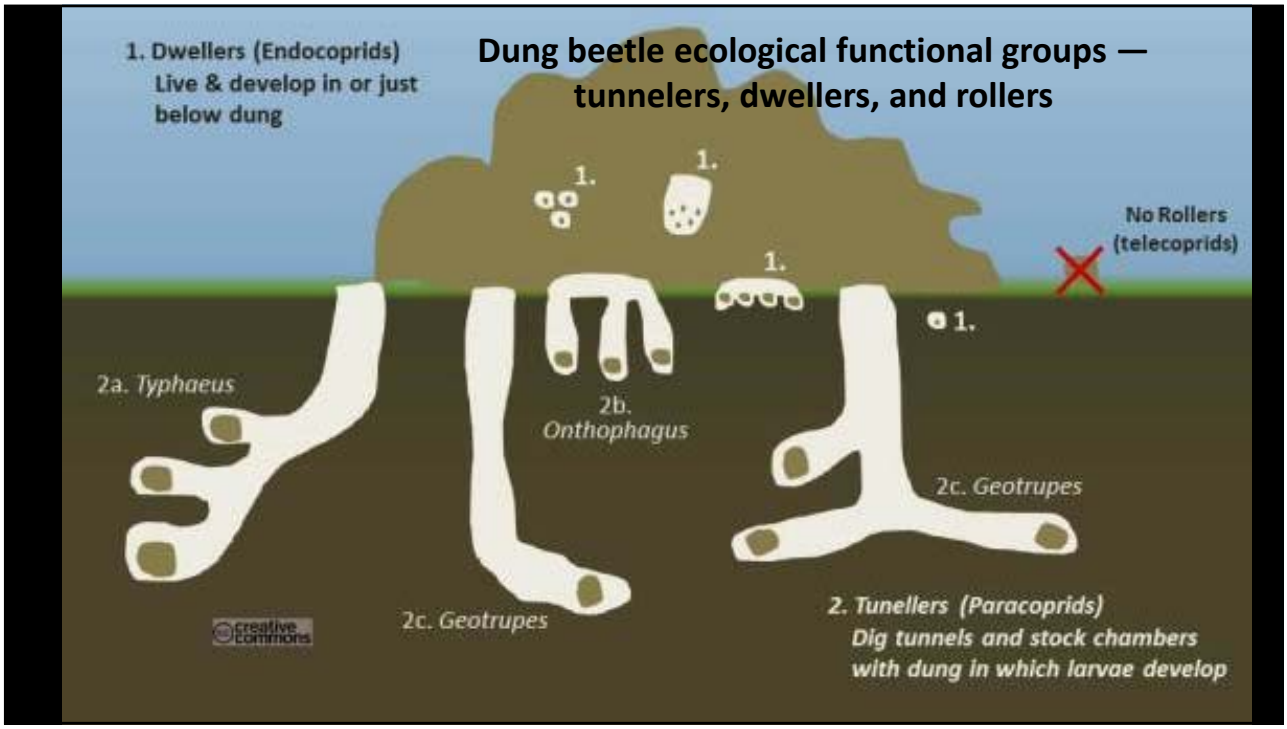
Bobolink in our goat & horse pasture, photos by Cherrie Nolden

Other Desirable Dung Insects

- Gold and brown rove beetle – eats adult flies and gnats visiting dung (*Ontholestes cingulatus*)
- Golden dung fly – adults eat other flies on manure, larvae eat manure (*Scathophaga stercoriaria*)

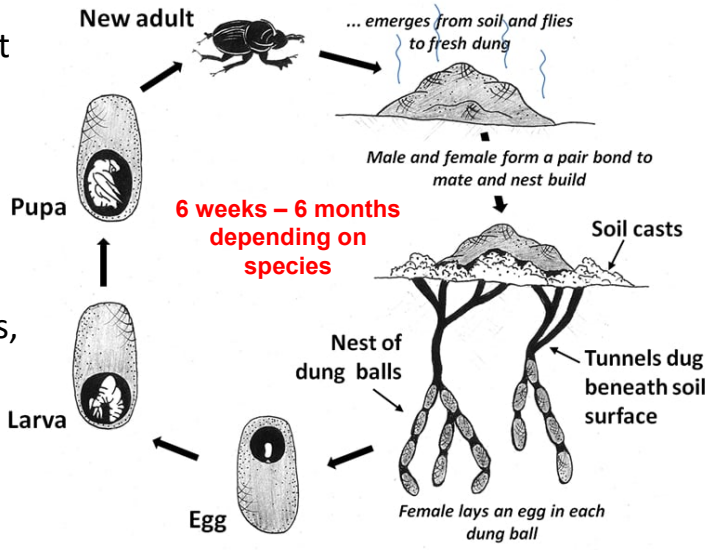
Rove Beetle, by Cherrie Nolden

Golden Dung Fly, Cherrie Nolden



Generalized Dung Beetle Life Cycle

- Eggs – larvae – pupae – adult – breed – hibernate
- Eggs are laid within dung balls
- Larvae (grubs) feed, live and develop in the dung balls
- Life cycle roughly 6-10 weeks, some up to 1 year
- Adults eat manure liquid component (microbes)
- Adults can live up to 3 years



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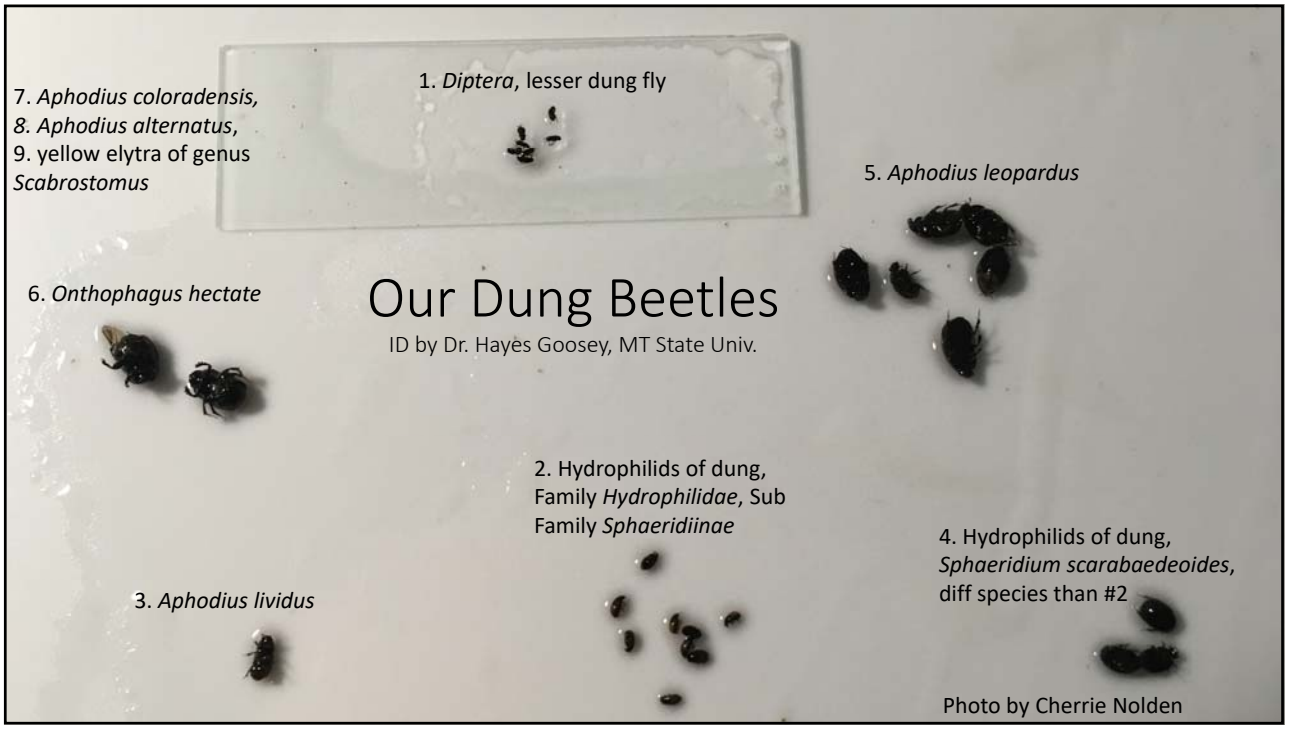


Our dung beetles in Dodgeville (southwest WI)

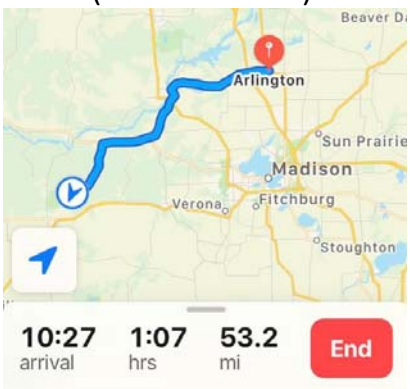
- Dwellers

Sphaeridium scarabaedeoides, Hydrophilid beetle

Dwellers not pictured: *A. leopardus, A. coloradensis, A. alternatus, A. rubripinnis, Euphoria india Scabrostomus* spp. *(yellow elytra), Histeridae* spp.
Photos by Cherrie Nolden

- Tunnelers

Species found at Arlington Research Station (central WI)



Our farm is only 53 miles from Arlington, yet there are only 3 species at Arlington that are also found on our farm; 12 species here, 8 at Arlington

Table 1. Identification and Brief Description of Dung Beetle Species Found at UW Arlington Agricultural Research Station Beef Grazing Farm

	***Aphodius badipes*** ("big black beetle")—an all black scarab beetle greater than 1 cm long with fossorial legs
	***Aphodius fimetarius*** ("red backs")—a mostly black, non-native scarab beetle of European origin with red elytra; less than 1 cm long, with fossorial legs
	***Aphodius granarius*** ("small black beetle")—an all black, non-native scarab beetle of European origin; less than 5 mm long, with fossorial legs
	**Aphodius rubripinnis** ("brown backs")—a scarab beetle chararcterized by reddish-brown elytra, less than 1 cm long, with fossorial legs
	***Onthophagous hecate***—an all black scarab beetle less than 1 cm long, with fossorial legs, exhibiting sexual polymorphism
	***Onthophagous nuchicornis***—Non-native beetle of European origin characterized by yellow and black elytra, 5 - 8 mm long, with fossorial legs, exhibiting sexual polymorphism
	***Sphaeridium scarabaeoides*** ("half brown backs")—beetle representing the family Hydrophillidae, characterized by brown, red and black elytra, and legs with spines; 5 - 7 mm long
	***Xestipyge conjunctum*** ("headless beetle")—beetle representing the family Histeridae, an all black, flat, glossy beetle less than 1 cm long, with a strongly retracted head and fossorial legs

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Manure Preferences

- Bovine
- Horse
- Goat
- Sheep
- Deer
- Rabbit
- Pig

- Most species visiting cow manure in Wisconsin also use manure from other species
  - A horse-specific beetle, *dichitomius*, is in the historical record for SE WI, which is the N edge of it's range
  - *A. prodromus* is common in sheep and horse manure, but doesn't use cattle manure as much
  - *A. lentus* uses deer pellets but not rabbit pellets. It's found in human and pig manure too
  - *A. leopardus* is common in deer manure, but we've found it in our horse and cow manure
- The moist texture of cow patties are beneficial for the hydrophilid species

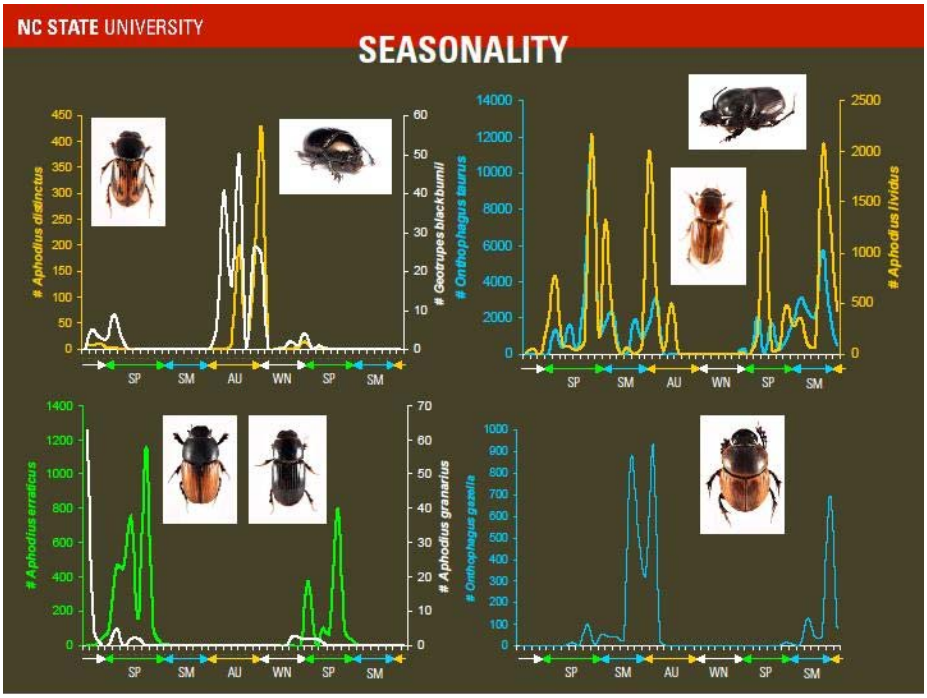
Photos by Cherrie Nolden

Tunneler Activity

- Soil brought to surface: bioturbation
- Tunnel lined with manure
- Manure balls with an egg per ball in tunnel
- Biochar buried in sand for CEC

Photos by Cherrie Nolden

Weather and time of year influences species and numbers



Beetles that feed and/or breed in dung

- Coprophages:
  - *Silphidae*
  - *Staphylinidae*
  - *Hydrophilidae*
  - *Geotrupidae*
  - *Scarabaeidae*

- Predatory:
  - *Carabidae*
  - *Histeridae*
  - *Hydrophilidae*
  - *Staphylinidae*

The true "dung beetles" are a species found in the family *Scarabaeidae* (the 2 subfamilies *Aphodiinae* and *Scarabaeinae*)

Slide content from Dr Nadine Kriska's talk at GrassWorks 2020

Photos by Cherrie Nolden

Rotational Grazing Impacts on Beetles

- Fresh manure concentrated
- Animals moved forward before manure is trampled – good
- 20-40 days of rest before hoof action again
  - *Aphodius* spp are likely completing life cycles every 3-4 weeks (4-6 generations per summer)
  - *O. hecate* likely has 2 generations per summer.
- Manure not disturbed by same species grazing on next rotation

Strongyles in horse manure, photo by Cherrie Nolden

Gut worm life cycle

- Adults live in the gut
- Eggs are shed in dung
- Eggs hatch into larvae
- Five larval stages
- 3LL stage is the infective stage

Dung Beetle Solutions International

ecological solutions for the Australian environment — dung beetle sales, research, workshops with Dr Bernard Doube

Drenches and pastes:

Consider your dung beetles when using parasiticides

- Mectins – most kill dung beetles
- 'White' drenches: BZ or benzimidazole
- 'Clear' drenches: LV eg levamisole
- Many others

Controlling gut worms

- Drenches and pastes
- Natural immunity
- Pasture spelling
- Cross-grazing
- Dung beetles
- Pathogens

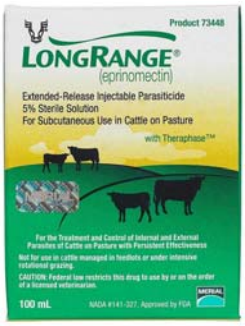
Toxic mectins: Ivermectin
Doramectin
Eprinomectin

Beetle-friendly: Moxidectin: EQUEST, CYDECTIN, MOXIMAX

Dung Beetle Innovations: https://youtu.be/OB5h2eQyiss

Dung Beetle Population Limiters

- Macrocyclic lactones (ivermectin, but moxidectin not as bad) [1]
- Pyrethroids
- Harrowing
- Trampling
- Tillage
- Chickens
- Wild birds, rodents, bats
- >30 miles from organic manure source
- Weather



JP Lumaret

Hump-backed larva of *Onthophagus vacca* (L.)

Aphodius constans Duft.

[1]Wardhaugh et al., 1993. Vet Parasitol. 48:139-157, Wardhaugh et al., 2001. Aust. Vet. Journal 79:125-132
[2]Kaufman et al., 1981. J Agric Food Chem 29: 239-245.

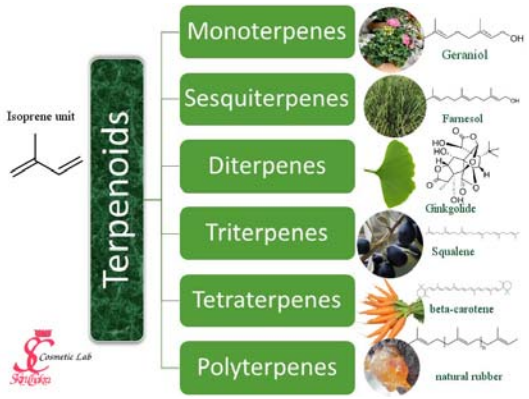
Organic Anthelmintics

Activity against Helminths	Plant Secondary Metabolite (PSM)	Reference
Inhibit energy metabolism	Tannins	(de Macedo et al., 2015)
Cause epidermal lesions	Adenine, ascorbic acid, chymopapain, caricain, genistein, glycyl endopeptidase, lutein, malic acid, papain	(Duke 1992; Piluzza et al. 2014; Vieriera et al. 2001)
Decrease motor activity	Tannins, saponins	(Athanasiadou and Kyriazakis 2004; Hoste et al. 2006; Williams et al. 2014)
	Terpenoids	(Athanasiadou and Kyriazakis 2004)
	Caffeic acid	(Cowan 1999)
Inhibit transformation of eggs to larvae	Tannins	(Athanasiadou and Kyriazakis 2004)

French, K., J. Harvey, J. McCullagh. 2018. Targeted and Untargeted Metabolic Profiling of Wild Grassland Plants identifies Antibiotic and Anthelmintic Compounds Targeting Pathogen Physiology, Metabolism and Reproduction. Nature Scientific Reports. 8:1695.
French, K. 2018. Plant-Based Solutions to Global Livestock Anthelmintic Resistance. Ethnobotany Letters. 9(2):110-123.

Midwestern plants containing anthelmintic PSMs

- Tannins
  - Chicory
  - Plantain
  - Birdsfoot trefoil
  - Walnut
  - Black locust
  - Oak
  - Raspberry
  - Poison ivy
  - Wormwood
  - Aronia
- Terpenoids
  - Pine
  - Bedstraw
  - Cedar
  - Ginkgo
  - Hemp
- Caffeic acid
  - Tobacco
  - Artichoke
  - Wintergreen
  - Heal All
- Saponins
  - Alfalfa
  - Plantain
  - Sunflower
  - Wild yam
  - Asparagus
  - Garlic
  - Tomatoes
  - Potatoes
  - Bindweed
  - Horsenettle



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French, K. 2018. Plant-Based Solutions to Global Livestock Anthelmintic Resistance. Ethnobotany Letters. 9(2):110-123.

Dung beetles control gut worm parasites

Sheep Manure Trt:
- Surface dung
- Manual burial by humans
- Buried by beetles

Infective Larvae Emerging
- Many
- Many more
- NONE

Dung beetle activity:
- Kills worms when pads dry out faster with active dung beetle populations
- Kills worms, larvae and eggs of parasite species that are buried with the dung and serve as food for the emerging dung beetle larvae

Research and photos by Dung Beetle Express N-NSW

Earthworms and Roots

Earthworm followed the tunnel down

Earthworm casts deep in the soil

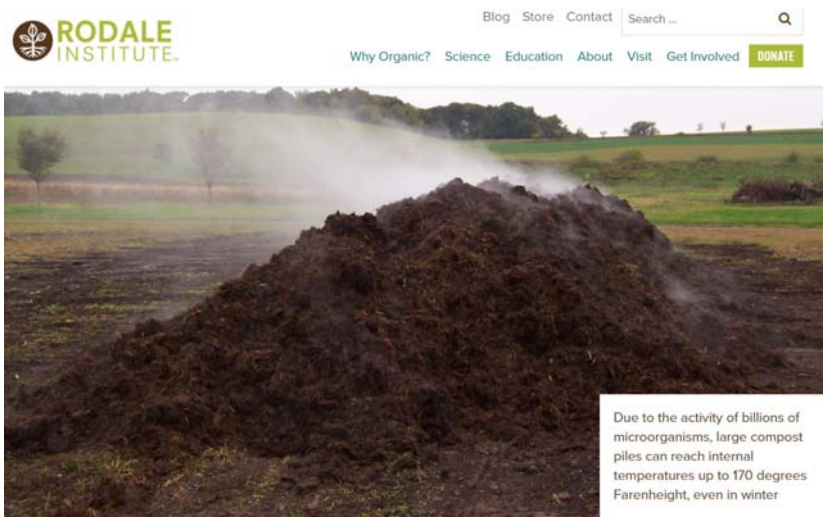
Roots into the subsoil

Dung Beetle Solutions International

ecological solutions for the Australian environment — dung beetle sales, research, workshops with Dr Bernard Doube

Dung Beetles in Compost

- They don't use compost, except for *Euphoria india*
- Nearly all are attracted to very fresh manure
- Adult beetles drink the liquid part of manure
- Beetle larvae eat larvae of fly species or the manure, depending on beetle type



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Environmental Benefits of Dung Beetles

- Facilitate dung removal
- Transport dung derived nitrogen (DDN) into soil
  - Microbial ammonification
  - Microbial nitrification
  - DDN uptake by plants
- Transport cations (P, K, Mg) into the soil
- Reduce need for applied fertilizers
- Reduce GHG emissions
- Herbage growth/productivity
- Change botanical composition
- Water percolation and retention
- Increase soil organic matter

Table 1
ANOVA results for herbaceous plant biomass, water infiltration rate and protein content measurements taken one and six months post the applications of dung and beetles. Treatments were: dung + dung beetles (n = 4); dung only (n = 4); and control/no dung, no dung beetles (n = 4).

	SS	df	MS	F	p
One month post applications					
Herbaceous plant biomass ($g.m^{-2}$)	15121.61	2	7560.81	5.98	0.02
Water infiltration rate ($mm.h^{-1}$)	22874.90	2	11437.45	75.33	< 0.0001
Protein content (%)	0.18	2	0.09	0.05	0.95
Six months post applications					
Herbaceous plant biomass ($g.m^{-2}$)	43702.33	2	21851.17	5.41	0.03
Water infiltration rate ($mm.h^{-1}$)	27941.99	2	13970.99	118.72	< 0.0001
Protein content (%)	6.08	2	3.04	2.97	0.10

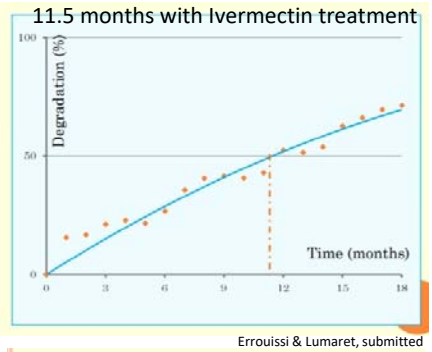
Badenhorst et al., 2018. Dung beetle activity improves herbaceous plant growth and soil properties on confinements simulating reclaimed mined land in South Africa. Applied Soil Ecology 132:53-59

Patty Breakdown Time

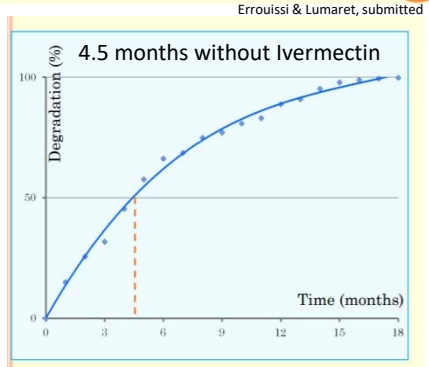
- Canada
  - Slowdown in the degradation rate of dung associated with the reduction of insect activity
  - Direct addition of ivermectin to dung (spiked dung) at concentration equivalent to the levels observed in dung of treated animals:
    - Droppings little degraded after 340 days or exposure
    - Control dung extensively degraded after 80 days

  (Floate, Bull. Entomol. Res. 88 (1998) 25-35)
- Australia
  - A field study confirms these findings

  (Dadour, Cook, Neesam, Bull Entomol. Res. 80 (1999) 119-123)



Errouissi & Lumaret, submitted



Forage fouling, grazing avoidance

- Zone of repugnance is an area 5x the size of the dung itself that is avoided by same species grazing animals (Fincher, 1981)
- Pasture fouling by dung can significantly reduce the area available for grazing
  - Five cows will decrease the effective area of pasture by one acre over one year (Bornemissza, 1960)
  - Economic analysis estimated that pasture fouling causes an annual loss of 7.63 kg of beef per head of cattle and places the cost of reduced pasture fouling at $122 million per annum (Losey & Vaughan, 2006)
- Dung beetles break down the manure pats, grass regrows, and livestock refuse less

Dung beetles transport cations into the soil

Dung beetles have the potential to improve pastures through the incorporation of manure into pasture soils. Two dung beetles, *O. gazella* and *O. taurus*, were evaluated in the laboratory for improved soil quality. The test soil was a coastal plain sandy-loam, common to eastern North Carolina. Treatments included bovine dung alone, dung plus *O. gazella*, dung plus *O. taurus*, and a no-dung control. The presence of beetles improved levels of P, K, Mg, and the sum of the cations in soil beneath the dung pat (Table 2).

Table 2. Analysis of soil treatments, using Mehlich[3] Extraction (North Carolina Department of Agriculture and Consumer Services).

Treatment	P (mg/dm^3)	K ($meq/100cm^3$)	Mg ($meq/100cm^3$)	Sum Cations ($meq/100cm^3$)
Sandy-loam Pre-treatment	99.40	0.08	0.53	1.66
Sandy-loam + Dung	174.73	0.18	0.87	2.64
Sandy-loam + Dung + *O. gazella*	204.57	0.25	1.06	3.35
Sandy-loam + Dung + *O. taurus*	196.01	0.23	0.98	3.04

Nolden, C.A. 2025. Dung Beetles in Southern Wisconsin.

Water percolation improvement

- Tunneling and improvements to the physical structure of soils have a "flow-on" effect which can include:
  - Improved water infiltration reduces surface ponding, assists agricultural inputs (lime, fertilizers) to enter the upper soil profile and reduce the level of contaminants entering the waterways… (Waterhouse 1974; Bormemissza 1976; Doube 2005b)
  - …which leads to improved water quality (Doube 2008)

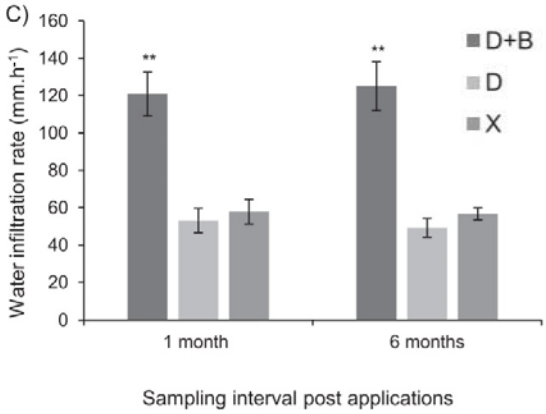
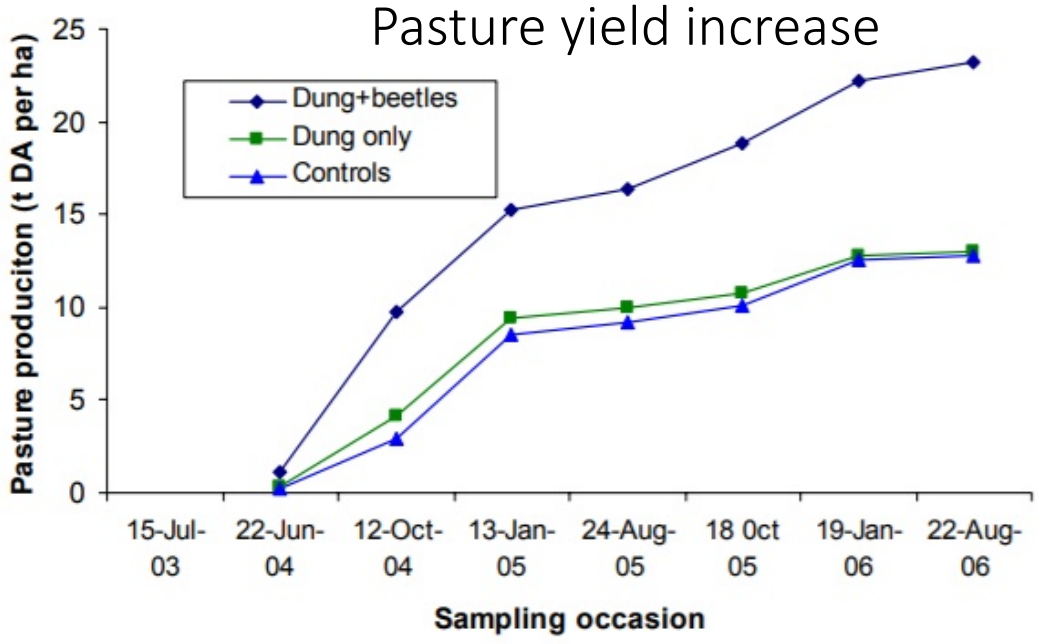


Fig. 1. Mean ± SE values for A – herbaceous plant biomass yield ($g.m^{-2}$), B – herbaceous plant crude protein content (%) and C – water infiltration rate ($mm.h^{-1}$) measurements taken one and six months post the applications of dung and beetles. Treatments were: dung + dung beetles (D + B; n = 4); dung only (D; n = 4); and control/no dung, no dung beetles (X; n = 4) [$*p \leq 0.05$; $**p \leq 0.01$].

Badenhorst et al., 2018. Dung beetle activity improves herbaceous plant growth and soil properties on confinements simulating reclaimed mined land in South Africa. Applied Soil Ecology 132:53-59

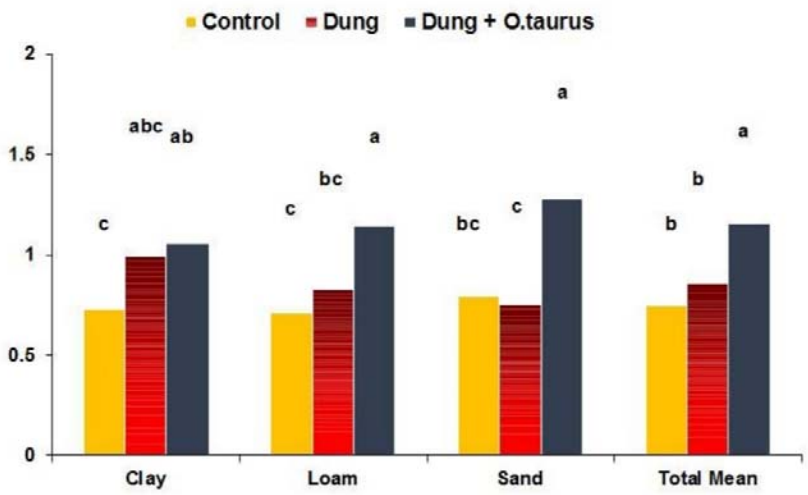
Pasture yield increase



2008, Pasture growth and environmental benefits of dung beetles to the southern Australian cattle industry. Technical report. Dung Beetle Solutions International.

Sudan grass mean dry weights increase

Dung beetles improved dry matter production significantly over manure applications without dung beetles and control treatments in Loam and Sand, and over control in Clay soils



2015, Dung beetles-their usefulness in the pasture ecosystem and what affects their populations. Proceedings 2015 NE Pasture Consortium Annual Conference

Transport dung derived nitrogen into soil

TABLE 2. Dung removal, nitrogen and carbon loss from the dung.

Experimental treatments and controls		After 1 month: Dung removed (% initial d.w.)	After 1 month: Total N in residual dung (g N)	After 1 month: Organic C in residual dung (g C)	After 1 yr: Dung removed (% initial d.w.)	After 1 yr: Total N in residual dung (g N)	After 1 yr: Organic C in residual dung (g C)
Controls	Dung-only	13 ± 1.5	1.49 ± 0.26	26.26 ± 2.36	58 ± 12	0.77 ± 0.37	10.71 ± 4.97
Dwellers	Dwe1	23 ± 7	1.13 ± 0.14	22.11 ± 2.10	83 ± 5	0.35 ± 0.13	4.86 ± 1.60
	Dwe4	24 ± 12	1.13 ± 0.17	21.79 ± 3.52	85 ± 4	0.27 ± 0.08	4.24 ± 1.33
Tunnelers	Tun1	41 ± 20	1.00 ± 0.36	17.77 ± 5.99	70 ± 8	0.56 ± 0.09	7.70 ± 1.17
	Tun4	57 ± 33	0.66 ± 0.54	11.88 ± 9.55	90 ± 8	0.24 ± 0.12	3.38 ± 1.70

Notes: Dung removed expressed as the percentage of initial dry dung weight (d.w.), total N and organic C in the residual dung after 1 month and 1 yr for dwellers, tunnelers and controls. Data are means ± SE.

Nervo et al., 2017. Ecological functions provided by dung beetles are interlinked across space and time: evidence from 15N isotope tracing. Ecology. 98:433-446.

Reduce manure GHG emissions

By rapidly manipulating fresh dung, dung beetles will aerate wet dung pads, thereby reduce anaerobic conditions needed for methane production

(Jarvis et al 1995; Holter 1996)

Photo by Cherrie Nolden

Challenges with Dung Beetles

- Attracting a diversity
- Supporting a large effective population
- Half the year is too cold
- No rollers here for livestock
- Most species at our farm are dwellers
- Differing life history strategies and management strategies by species
- Many producers rely on harmful chemical dewormers for pest management

Sampling of Dung Beetles on 1dr Acres Farm, Dodgeville, WI, by Cherrie Nolden

Summary: Dung Beetle Benefits

- <u>Increased:</u>
  - Organic carbon capture
  - Infiltration rates
  - Pasture productivity
  - Nutrient recycling
  - Plant nitrogen content, protein levels, height & biomass
  - Micro organisms
  - Earthworm biomass & depth
  - Soil structure & health
  - Grass root biomass & depth
  - Water & nutrient conservation
  - Water quality – leachate & non-leachate
- <u>Reduced:</u>
  - Forage fouling
  - Surface runoff
  - Water pollution
  - Gastrointestingal parasites of livestock
  - Horn flies
  - Face flies

Tunneler (*O. hecate*) activity buried horse manure and pushed this soil to the surface (bioturbation). Photo by Cherrie Nolden

Questions?

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