Insects as Agents of Improved Rangeland Quality and Cattle Production

Sean D. Whipple, Panhandle Research and Extension Center,
University of Nebraska-Lincoln, Scottsbluff, NE 69361

Dung Beetle Background *Adapted from Whipple (2011)

Dung beetles are a relatively small group of Scarab beetles with approximately 7,000 species worldwide. They occur on every continent but Antarctica, and are most diverse in Africa, where more than 2,000 species occur (Hanski and Cambefort 1991). Dung beetles are extremely important ecologically and are a major component of the biological removal of dung and control of pests and parasites which use dung for breeding (Fincher 1973). In the state of Nebraska, beef production is the most economically valuable industry (Veneman et al. 2004). Dung beetles are estimated to save farmers and ranchers $380 million annually in the U.S. (Losey and Vaughan 2006) based on yield loss, pesticide applications, and fertilizer use (Walters 2008). Not included in this estimation are health costs and environmental problems from pests and pesticides (Walters 2008). This is especially important considering approximately $800 million are spent annually to control livestock pests in the U.S. alone (Fincher 1981, Griffith 1997). Other than their role as decomposers, dung beetles are a likely candidate for use in the measure of biodiversity (Halffter and Favila 1993, Kremen et al. 1993), and are also involved in the pollination (Sakai and Inoue 1999) and seed dispersal of some plants (Andresen and Feer 2005, Nichols et al. 2008).

Individual cattle produce approximately 10-20 dung pats every day (Rougan 1987), with each pat covering a surface area of approximately 0.82 m^2 (Bornemissza 1960, Fincher 1981). While dung may be broken down by weathering (White 1960, Bastiman 1970) and by other organisms such as earthworms, ants, and termites (Denholm-Young 1978, Holter 1979), some areas in the southern U.S. rely more heavily on dung beetles (Merritt and Anderson 1977, Lumaret and Kirk 1987). Dung beetles significantly increase the rate of dung decomposition (Wratten and Forbes 1996), with larvae being able to consume up to 100% of their body weight per day until pupation (Holter 1974). Additionally, cattle will not graze in close proximity to their own feces (Dohi et al. 1991), and it has also been concluded that the nutritional quality of the dung of grazing mammals is directly related to range health (Edwards 1991). Undegraded dung can prevent the growth of vegetation, resulting in an area that will remain ungrazed by cattle for up to two years (Anderson et al. 1984).

Manure is a breeding ground for pests and parasites. The horn fly, *Haematobia irritans* L., causes an estimated $730 million annual loss to the cattle industry (Drummond et al. 1981). Dung beetles reduce horn flies by 95%, bush flies by 80-100%, and result in nine times fewer parasite produced (Bornemissza 1970, 1976). This is staggering when it is considered that over 100 adult bush flies (*Musca vetustissima* Walker) can emerge from a 1000 cc. dung pat in Australia (Bornemissza 1970). Dung beetle activity has been shown to reduce numbers (Bryan 1973, 1976), resurgence (Reinecke 1960), and migration (Fincher 1973) of parasitic larvae within feces.

Up to 56% of cattle in the U.S. are treated with insecticides to control dipterans and internal parasites (Losey and Vaughan 2006, Scholtz et al. 2009). Krüger and Scholtz (1996) observed that treating cattle with Ivermectin can hinder development of the dung beetle *Euoniticellus intermedius* (Reiche) for up to 28 days. Some veterinary pharmaceuticals can reduce survival and be fatal to dung beetle populations (Madsen et al. 1990, Krüger and Scholtz

1996, Floate et al. 2005). If treatment is necessary, it is recommended to be done when dung beetles are inactive or by using dusts and sprays (Krüger and Scholtz 1996).

With overstocking and drought, as much as 85% of a pasture's biomass can be consumed by herbivores (Olechowicz 1974). Hutton and Giller (2003) reported that dung beetle numbers, diversity, and species richness were significantly higher in Northern Ireland on organic rangelands compared to rangeland that was roughly and intensively grazed. Dung beetles efficiently cycle nutrients into the soil and create healthier rangelands and reduce greenhouse gas emissions (Halffter and Matthews 1966, Mittal 1993, Estrada et al. 1998, Walters 2008). If dung is not removed by the beetles, 80% of the nitrogen is lost to the atmosphere (Gillard 1967). In addition, burial of animal dung by the beetles increases soil aeration and the eventual leaching of water and nutrients into the soil (Bornemissza 1960, Bang et al. 2005). Soil aeration resulting from dung burial (Mittal 1993) enhances the role dung beetles play in nutrient cycling (Halffter and Matthews 1966, Mittal 1993, Estrada et al. 1998). Soil aeration lowers runoff of surface wastes and aids in reduction of water contamination and algal blooms. (Walters 2008).

When stocking rates are high, dung beetles may become ineffective. Exceeding recommended stocking rates for livestock results in reduced forage, increased dung, and a decrease in livestock yield (Burton 1972). Overgrazing can result in reduced surface cover, increased surface temperature, increased runoff, reduced soil moisture, and an eventual change in plant community composition. Intensive and rough grazing has been observed to reduce dung beetle abundance (Hutton and Giller 2003).

Dung beetles have adapted to fill numerous niches in a wide variety of ecosystems and many are highly specialized (Hanski and Cambefort 1991). The subfamilies Aphodiinae and family Geotrupinae have many specialist dung beetle species that feed on resources other than dung (Howden 1955, Halffter and Edmonds 1982). Depending upon species, dung beetles may have specific preference toward dung and dung condition (Doube 1987, Yasuda 1987), as well as dung odor (Dormont et al. 2004). Dung beetles have also been shown to segregate based upon habitat and soil type (Peck and Forsyth 1982, Doube 1983). Species differ in their nocturnal or diurnal activity (Hanski and Cambefort 1991), as well as exhibit variances in seasonal activity (Scholtz et al. 2009). Dung beetle numbers and species also vary depending upon light and light intensity (Ratcliffe and Paulsen 2008). Additionally, beetles respond differently to elevation, with higher temperatures at low altitudes being optimal (Medina et al. 2002).

For more information on dung beetles in Nebraska, see Whipple, S. D. 2011. Dung beetle ecology: Habitat and food preference, hypoxia tolerance, and genetic variability. Dissertation, University of Nebraska-Lincoln. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1012&context=entomologydiss

Ongoing Research

We are currently conducting research on dung beetles as agents of biocontrol in rangeland systems through the manipulation of cattle diet. Although there have been several studies of feeding preference and niche partitioning of various dung beetle species, our understanding of the interaction among livestock diet, bacterial communities, dung beetles, pest flies, and other parasites is limited. We seek to answer the questions: 1) *How does attractiveness of dung to dung beetles, pest flies, and parasites vary based on quality of livestock diet?* 2) *How does grazing strategy impact dung beetle abundance and species diversity?*

It is known that cattle diet can impact fecal bacterial community composition (Durso *et al.* 2012), and that forage quality can impact dung beetle behavior. Preliminary studies indicate strong dung beetle preference for dung from cattle fed by highly digestible diets (Fig. 1). These results show differences in beetle attraction based on livestock forage. If beetles cannot adequately degrade dung of low quality, there are implications that ranchers and range managers in Nebraska may not be receiving adequate decomposition of dung on their rangelands. This inhibits the control of flies (since dung piles remain intact) and allows for the survival of other manure-borne animal pests. This also reduces forage availability and nutrient cycling because cattle avoid grazing in areas with intact manure pats (Dohi *et al.* 1991).

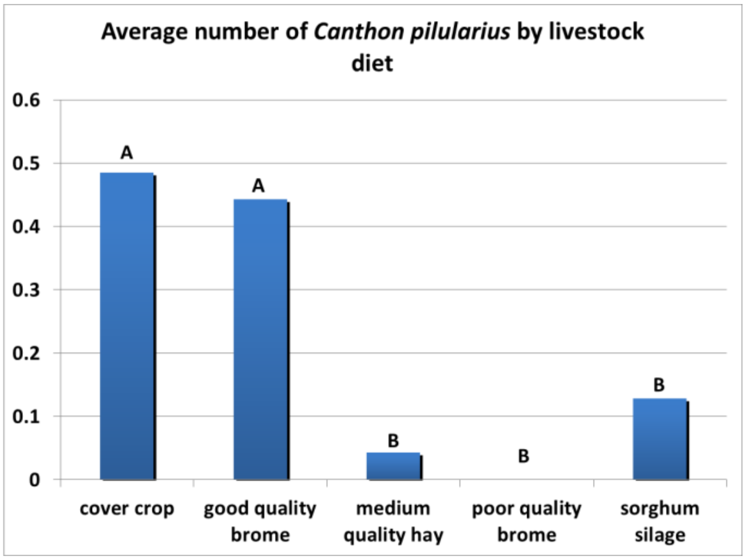

Fig 1. Preliminary field data from summer 2012 showing differences in attraction of the dung beetle *Canthon pilularius* to dung of cattle fed variable diet quality.

Further preliminary work (from Whipple and Hoback 2012) shows that even when diet is standardized, dung beetle attraction across mammalian species differs markedly (Fig. 2), indicating that diet alone is not the only deciding factor in beetle attraction, and suggesting a role for bacterial communities and their associated volatiles. Understanding the interactions among cattle diets, bacterial flora of manure, and their volatiles has the potential to improve agricultural production through the discovery of novel strategies for enhancing biologically-based pest management of cattle.

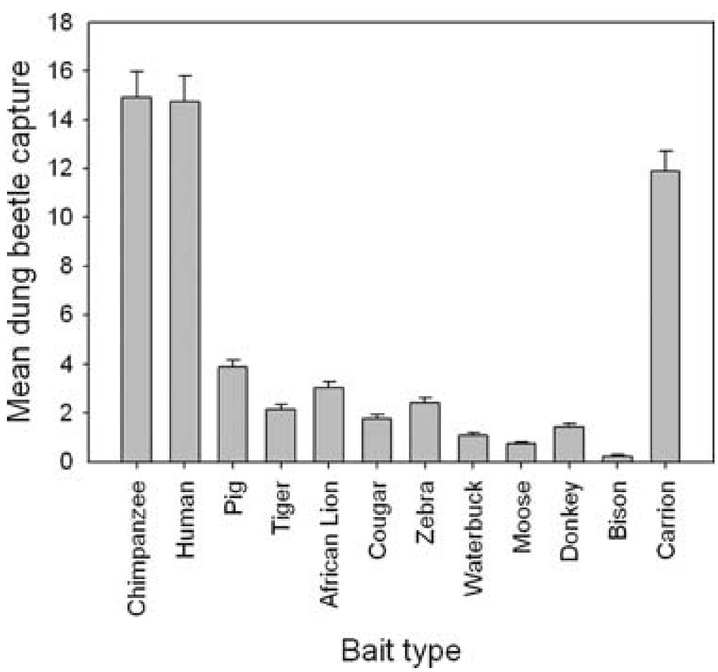

Fig 2. Mean dung beetle capture using mammalian herbivore, carnivore, and omnivore dung.

Preliminary data from two years of dung beetle pitfall sampling in western Nebraska at two bordering 4,000 ha ranches with similar stocking rates (~900 cattle) but different management strategies yielded twice the number of dung beetle species and more than six times the total number of dung beetles under organically managed rotational grazing compared to conventionally managed continuous grazing. A total of 3,287 dung beetles from 15 species were captured on the organic ranch utilizing rotational grazing, while only 480 beetles from eight species were collected from continuously grazed rangeland that utilized pesticides (Whipple 2011). This research stresses that range and livestock management practices impact dung beetles, and their potential benefits to agriculture.

Species	Rotational Grazing	Continuous Grazing
Aphodius coloradensis	156	2
Aphodius distinctus	365	4
Aphodius erraticus	28	0
Aphodius fimetarius	2	6
Aphodius granarius	32	0
Aphodius prodromus	8	0
Aphodius testaceiventris	3	0
Aphodius walshii	63	0
Canthon pilularius	53	1
Copris fricator	266	29
Melanocanthon nigricornis	13	0
Onthophagus hecate	716	191
Onthophagus orpheus pseudorpheus	48	158
Onthophagus pennsylvanicus	1,175	89
Phanaeus vindex	359	0
Totals	3,287	480

Future Research

In 2014, research will take place on the University of Nebraska-Lincoln Barta Brothers Ranch, which is a 2,350 ha research ranch in the eastern Nebraska Sandhills. As it concerns dung beetles, our objectives are to: 1) *measure the macro-scale spatial and temporal distribution of the nutrient pulses in relation to grazing strategies, and* 2) d*etermine the micro-scale vertical and lateral transport/movement of nutrients from dung into soil by physical and biological (e.g., dung beetle) processes under varied moisture conditions.* We will be assessing dung decomposition with and without dung beetle colonization.

Following the methods of Whipple and Hoback (2012), dung beetle abundance and diversity will be monitored by examining dung pats and pitfall traps on ultra-high stocking density, low stocking density, and hayed pastures at Barta Brothers and cooperating ranches. Subsequently, vertical and lateral transport/movement of nutrients in the dung by dung beetles will be monitored. This will allow determination of optimal grazing strategies for dung beetle conservation, as well as the role of dung beetles in nutrient cycling depending upon grazing strategy.

Literature Cited

Andresen, E. and F. Feer. 2005. The role of dung beetles as secondary seed dispersers and their effect on plant regeneration in tropical rainforests. Pp. 331-349. In: P. M. Forget, J. E. Lambert, P. E. Hulme, and S. B. Vander Wall (eds). Seed fate: Predation, dispersal and seedling establishment. CABI International, Oxon, U.K.

Bang, H. S., J. H. Lee, O. S. Kwon, Y. E. Na, Y. S. Jang, and W. H. Kim. 2005. Effects of paracoprid dung beetles (Coleoptera: Scarabaeidae) on the growth of pasture herbage and on the underlying soil. *Applied Soil Ecology* 29: 165-171.

Bastiman, B. 1970. Problems of pasture contamination and herbage rejection under intensive grazing. *11th Progress Report Experimental Husbandry and Experimental Horticultural Stations, NAAS* 62-69.

Bornemissza, G. F. 1960. Could dung eating insects improve our pastures? *Journal of the Australian Institute of Agricultural Science 7*5: 54-56.

Bornemissza, G. F. 1970. Insectary studies on the control of dung breeding flies by the activity of the dung beetle, *Onthophagus gazelle* F. (Coleoptera: Scarabaeidae). *Australian Journal of Entomology* 9(1): 31-41.

Bornemissza, G. F. 1976. The Australian dung beetle project, 1965-1975. *Australian Meat Research Committee Review* 30: 1-30.

Bryan, R. P. 1973. The effects of dung beetle activity on the number of parasitic gastrointestinal helminth larvae recovered from pasture samples. *Australian Journal of Agricultural Research* 24: 161-168.

Bryan, R. P. 1976. The effect of the dung beetle, *Onthophagus gazella*, on the ecology of the infective larvae of gastrointestinal nematodes of cattle. *Australian Journal of Agricultural Research* 27:567-574.

Burton, G. W. 1972. Can the south become the world's greatest grassland? *The Progressive Farmer* 87: 22-24.

Denholm-Young, P. A. 1978. Studies of decomposing cattle dung and its associated fauna. Ph.D. Dissertation, Oxford University, U.K.

Dohi, H., A. Yamada, and S. Entsu. 1991. Cattle feeding deterrents emitted from cattle feces. *Journal of Chemical Ecology* 17(6): 1197-203.

Dormont, L., G. Epinat, and J. Lumaret. 2004. Trophic preferences mediated by olfactory cues in dung beetles colonizing cattle and horse dung. *Environmental Entomology* 33(2): 370-377.

Doube, B. 1983. The habitat preference of some bovine dung beetles (Coleoptera: Scarabaeida) in Hluhluwe Game Reserve, South Africa. *Bulletin of Entomological Research* 73: 357-371.

Doube, B. 1987. Spatial and temporal organization in communities associated with dung pads and carcasses. Pp. 255-280. In: Gee, J. H. R., and P. S. Giller (eds). Organization of Communities Past and Present. Blackwell Scientific Publications, Oxford, U.K.

Drummond, R. O., G. Lambert, H. E. Smalley, and C. E. Terrill. 1981. Estimated losses to livestock pests. *Handbook of Pest Management in Agriculture* 1: 111-127.

Estrada, A., R. Coates-Estrada, A. Anzunes, and P. Cammanaro. 1998. Dung and carrion beetles in tropical rain forest fragments and agricultural habitats at Los Tuxtlas, Mexico. *Journal of Tropical Ecology* 14: 577-593.

Fincher, G. T. 1973. Dung beetles as biological control agents for gastrointestinal parasites of livestock. *The Journal of Parasitology* 59(2): 396-399.

Fincher, G. T. 1981. The potential value of dung beetles in pasture ecosystems. *Journal of the Georgia Entomological Society* 16(1): 316-333.

Floate, K. D., K. G. Wardhaugh, A. B. A. Boxall, and T. N. Sherratt. 2005. Fecal residues of veterinary parasiticides: Nontarget effects in the pasture environment. *Annual Review of Entomology* 50: 153-179.

Gillard, P. 1967. Coprophagous beetles in pasture ecosystems. *Journal of the Australian Institute of Agricultural Science* 33: 30–34.

Halffter, G. and W. D. Edmonds. 1982. The nesting behavior of dung beetles (Scarabaeinae): An ecological and evolutive approach. Instituto de Ecologia, Mexico.

Halffter, G. and M. E. Favila. 1993. The Scarabaeinae (Insecta: Coleoptera): An animal group for analysis, inventorying and monitoring biodiversity in tropical rain forest and modified landscapes. *Biology International* 27: 15-21.

Halffter, G. and E. G. Matthews. 1966. The natural history of dung beetles of the subfamily Scarabaeinae (Coleoptera, Scarabaeidae). *Folia Entomologica Mexicana* 12-14: 1-312.

Hanski, I. and Y. Cambefort. 1991. Dung beetle ecology. Princeton University Press. Princeton, New Jersey. 481 pp.

Holter, P. 1974. Food utilization of dung-eating *Aphodius* larvae. *Oikos* 25: 71-79.

Holter, P. 1979. Effect of dung beetles (*Aphodius* spp.) and earthworms on the disappearance of cattle dung. *Oikos* 32: 393-402.

Howden, H. F. 1955. Biology and taxonomy of North American beetles of the subfamily Geotrupinae, with revisions of the genera *Bolbocerosome*, *Eucanthus*, *Geotrupes*, and *Peltotrupes* (Scarabaeidae). *Proceedings of the U.S. National Museum* 104: 151-319.

Hutton, S. A. and P. S. Giller. 2003. The effects of the intensification of agriculture on northern temperate dung beetle communities. *Journal of Applied Ecology* 40: 994-1007.

Kremen, C., R. K. Colwell, T. L. Erwin, D. D. Murphy, R. F. Noss, and M. A. Sanjayan. 1993. Terrestrial arthropod assemblages: Their use in conservation planning. *Conservation Biology* 7: 796-808.

Krüger, K. and C. H. Scholtz. 1996. Lethal and sublethal effects of ivermectin on the dung-breeding bettles *Euoniticellus intermedius* (Reiche) and *Onitis alexis* Klug (Coleoptera, Scarabaeidae). *Agriculture, Ecosystems, and Environment* 61(2-3): 123-131.

Kryger, U., C. Deschodt, and C. H. Scholtz**.** 2005. Effects of fluazuron and ivermectin treatment of cattle on the structure of dung beetle communities. *Agriculture, Ecosystems, and Environment* 105(4): 649-656

Losey, J. E. and M. Vaughan. 2006. The economic value of ecological services provided by insects. *BioScience* 56: 311–323.

Lumaret, J. P. and A. A. Kirk. 1987. Ecology of dung beetles in the French Mediterranean region (Coleoptera: Scarabaeinae). *Acta Zoologica Mexicana* 24: 1-55.

Madsen, M., B. Overgaard Nielsen, P. Holter, O. C. Pedersen, J. Brochner Jespersen, K. M. Vagn Jensen, P. Nansen, and J. Gronvold. 1990. Treating cattle with Ivermectin: Effects on the fauna and decomposition of dung pats. *The Journal of Applied Ecology* 27(1): 1-15.

Medina, C., F. Escobar, and G. Catán. 2002. Diversity and habitat use of dung beetles in a restored Andean landscape. *Biotropica* 34:181–187.

Merritt, R. W. and J. R. Anderson. 1977. The effects of different pasture and rangeland ecosystems on the annual dynamics of insects in cattle droppings. *Hilgardia* 45(2): 31-71.
Mittal, I. C. 1993. Natural manuring and soil conditioning by dung beetles. *Tropical Ecology* 34: 150-159.
Nichols, E., S. Spector, J. Louzada, T. Larsen, S. Amezquita, and M. E. Favila. 2008. Ecological functions and ecosystem services provided by Scarabaeinae dung beetles. *Biological conservation* 141(6): 1461-1474.
Olechowicz, E. 1974. Analysis of a sheep pasture ecosystem in the Pieniny Mountains (The Carpathians). X. Sheep dung and the fauna colonizing it. *Ekologia Polska* 22: 589-616.
Peck, S. B. and A. Forsyth. 1982. Composition, structure and competitive behaviour in a guild of Ecuadorian rain forest dung beetles (Coleoptera: Scarabaeidae). *Canadian Journal of Zoology* 60: 1624-1634.
Ratcliffe, B. C., and M. J. Paulsen. 2008. The Scarabaeoid beetles of Nebraska (Coleoptera: Scarabaeoidea). *Bulletin of the University of Nebraska State Museum* 22: 1-570.
Rougan, D. 1987. Coléoptères coprophiles en zone sahélienne: étude biocénotique, comportement nidificateur, intervention dans le recyclage de la matiere organique du sol. Sc.D. thesis. University of Orleans, France.
Sakai, S., and T. Inoue. 1999. A new pollinating system: dung beetle pollination discovered in *Orchidantha inouei* (Lowiaceae: Zingiberales) in Sarawak, Malaysia. *American Journal of Botany* 86: 56-61.
Scholtz, C. H., A. L. V. Davis, and U. Kryger. 2009. Evolutionary Biology and Conservation of Dung Beetles. Pensoft Publishers. Sofia, Bulgaria. 567 pp.
Veneman, A. M., J. J. Jen, and R. R. Bosecker. 2004. 2002 Census of Agriculture: Nebraska state and county data. Volume 1, Geographic Area Series, Part 27. AC-02-A-27. 645 pp.
Walters, C. 2008. Dung Beetles: The greatest invention and a cowman's profits. Acres U.S.A. Austin, Texas.
Whipple, S. D. 2011. Dung beetle ecology: Habitat and food preference, hypoxia tolerance, and genetic variability. Dissertation, University of Nebraska-Lincoln.
Whipple, S.D. and W.W. Hoback. 2012. A comparison of dung beetle (Coleoptera: Scarabaeidae) attraction to native and exotic mammal dung. *Environmental Entomology* 41:238-244.
White, E. 1960. The distribution and subsequent disappearance of sheep dung in the Pennine moorland. *Journal of Animal Ecology* 29: 243-250.
Wratten, S. D. and A. B. Forbes. 1996. Environmental assessment of veterinary avermectins in temperate pastoral ecosystems. *Annual Applied Biology* 128: 329-348.
Yasuda, H. 1987. Differences in temporal utilization patterns of dung pats amongst three scarabaeid dung beetles. *Researches on Population Ecology* 29: 167-177.