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Disclaimer: This document does not reflect the opinions, scientific or otherwise, of SARE organization or personnel. This document is represented of discussions and demonstrations arising from grant activity and is intended to share opinions and findings but not to dictate actual practices or actual activities on the lands of others. The conclusions and opinions within this document are personal and not solid scientific data. The recommendations are specific only to the parcels listed as being in the project. The information is presented for demonstration purposes only. Even so, it is hoped that the information is useful for others to use in forming their own opinions and furthering their own learning. There is no warranty of completeness of information. In addition, no reference to products or active ingredients in this document is a recommendation for use of the product or any kind of prohibition to use the product. Pesticides must be applied legally, complying with all label directions and precautions on the pesticide container and any supplemental labeling and rules of state and federal pesticide regulatory agencies. There's no warranty of safety or effectiveness of any of the instructions or products described. This project was a not for profit activity and did not generate any proceeds.

A Dung Beetle's Place on Your Ranch

By Linda Simmons

CONTENTS

Project Components

Time frame: August 2014 to March 2016 with observations and data from 2013

Land parcels

1. 338 ac of native rangeland used as pasture with 5 paddocks used in rotational grazing and a dung beetle population easily observed in 2013, 2014 and damaged but surviving population in 2015.
2. 80 ac native rangeland used as pasture with two paddocks used in rotational grazing and a dung beetle population easily observed in 2013, 2014 and damaged but surviving population in 2015.
3. 160 ac smooth brome and native grass used as pasture with 5 paddocks used in rotational grazing and no observable dung beetle population, a history of spring ivermectin pour on applications on the cattle
4. Farmstead with sheep, goats, cattle and poultry adjacent to fly and dung beetle study area 1.

Livestock

1. 119 closely related pregnant Red Angus cross cows and 5 bulls
2. 71 Black Angus cross cows and 3 bulls
3. 225 ewes from farmstead 4.
4. 400+ feeder cattle including 2014 and 2015 calves from herd 1 and 2 and Holstein steers

Livestock systems

1. Rotational grazing native grassland on parcels 1 and 2 with herd 1 (98 and 21 head respectively)
2. Rotational grazing tame grassland, mostly smooth brome on parcel 3 with herd 2 (74 head).

Definitions

1. Active ingredient: the chemicals in a pesticide product that act to control the pests. Active ingredients must be identified by name on the pesticide product's label together with its percentage by weight.
2. Anthelmintic: a pesticide used to treat infections by internal parasites of livestock, humans or pets.
3. Biopesticides: an EPA term. The EPA definition:" Biopesticides are certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals. For example, canola oil and baking soda have pesticidal applications and are considered biopesticides. As of September 2015, there are 436 registered biopesticide active ingredients and 1401 active biopesticide product registrations. To use biopesticides effectively (and safely), however, users need to know a great deal about managing pests and must carefully follow all label directions."
4. Coccidian: organisms that cause the disease coccidiosis. They are classified in the genus Eimeria and often referred to as Eimeria spp or Eimeria, coccidea
5. Dung: manure or feces
6. Dung Beetles: arthropods in the order Coleoptera and family Scarabaeidae, are beetles that specialize in consuming the feces of other animals.
7. Macrocyclic lactones: a group of chemicals used as the active ingredient in many different products sold for control of parasites and flies in livestock in the US. Common macrocyclic lactones include abermectin, eprinectin, monodectin, ivermectin, and cydectin. The properties of each chemical and its

commercial formulations are different.

8. Mycorrhiza: relationships between fungi and plant roots that provide benefits to the plants and the fungi.
9. Pesticide: chemical labeled for use in controlling pests of livestock including anthelmintics, chemical wormers, fly control chemicals, pest control dusts and other commercially available forms. Biologically active manufactured chemicals for the destruction of pests including internal and external parasites and fly pests of livestock.
10. Pyrethrins: esters found in the plant extract pyrethrum. They are the active ingredient in pyrethrum, a plant extract, which kills insects.
11. Synthetic pyrethroids: a group of chemicals that are a similar to pyrethrines but are manufactured and have somewhat different properties. They include cyfluthrin, cypermethrin, permethrin.
12. Systemic insecticides: pesticides that enter the tissues of livestock and moves within the animal after application. They might be applied to the skin, injected, fed or given orally in a drench to livestock. Refer to a chart recently published by a reputable source such as University of Kentucky Cooperative Extension Service Bulletin ENT 11 - INSECT CONTROL FOR BEEF CATTLE - 2016 Prepared by Lee Townsend, Extension Entomologist.
13. Turn out: when livestock arrive at pasture, typically the beginning of a grazing season.

References list .....in order of citing

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"South Dakota Beetle Checklist" published by SDSU in 1975 and now shared online has been uploaded to SARE as one of the information products for this project grant at http://mysare.sare.org/sare_project/fnc14-977/

University of Maine Extension has published a dung beetle fact sheet online at http://umaine.edu/blueberries/factsheets/insects/194-beneficial-insect-series-3-dung-beetles/

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A literature of information on macrocyclic lactones is found in AOSIS Open Journals titled ‘A review on the effect of macrocyclic lactones on dung-dwelling insects: Toxicity of macrocyclic lactones to dung beetles’, Jacobs, C.T. & Scholtz, C.H., Onderstepoort 2015, *Journal of Veterinary Research* 82(1), Art. #858, 8 pages. http:// dx.doi.org/10.4102/ojvr. v82i1.858

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Video from an extensive, professional SARE project on parasite management in small ruminants at http://youtu.be/ZZQymZKe_hs is very highly recommended. The principles apply to all livestock.

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“Performance of the Nzi traps for biting flies in North America” *Bulletin of Entomological Research*, (2006) 96, 387–397. The authors include S. Mihok1 *, D.A. Carlson2, E.S. Krafsur3 and L.D. Foil4 1388 Church Street, Russell, Ontario, Canada, K4R 1A8: 2US Department of Agriculture, Agricultural Research Service, Center for Medical,Agricultural and Veterinary Entomology, 1600 SW 23rd Drive, Gainesville,Florida 32608, USA: 3Department of Entomology, Iowa State University,Ames, Iowa 50011-3222, USA: Department of Entomology, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803, USA More information on Nzi traps are posted on Research Gate and as information products on SARE project FNC14-977 http://mysare.sare.org/sare_project/fnc14-977

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Section One: How Pastures Work

Cycles Connect the Pasture Ecosystem. A pasture is a miniature ecosystem where the outputs include runoff, livestock or livestock products such as milk or beef and the inputs include rainfall, sunlight, the rancher's livestock turned out in the spring, mineral and feed supplements, flies blown in from the neighbors and any chemical pesticides. Within the pasture is a web of intersecting cycles. The nutrient cycle and the water cycle are the major cycles. Plants reproduce and have important times in their life cycles when their flowers must be pollinated and their seeds planted. In turn their pollinators have life cycles that require certain plants, not necessarily the ones they pollinate. Some insects also play a role in the burying of seeds and many play a role in soil structure because of their burrows. Some dung beetle species in South Dakota burrow into the soil and the extent of their influence is still unknown but it is probably overwhelmingly positive for plant regeneration and production. High plant production is, of course, positive for livestock production.

The principles of ecology apply as strongly to ranches and farms as they do to wild lands and oceans. The rangeland+livestock system is a food web full of cycles. The nutrient cycle and the water cycle are the two most important to livestock managers, but lesser known parts can make a huge difference in livestock production. One of those lesser known parts now considered an unsung hero is the dung beetle. This overlooked group of insects has finally been recognized for their large contribution to sanitation, soil health and forage production in pastures. Explaining the pest control and the nutrient cycling benefits that dung beetles supply is only possible by referring to the livestock pasture as an ecosystem.

A major concept in ecology is diversity. A pasture that is a remnant of untilled native rangeland has thousands of species of plants, insects and many unnoticed organisms from little brown sparrows to tiny mycorrhiza living in the soil. A pasture is more diverse than most farmed fields because the untilled soil is a home for many organisms, some that take years to grow and reproduce. Turtles are not the only long lived organism in pastures. Perennial grasses are very long lived plants compared to agricultural crops and native species of grass can live for more than 15 years. Dung beetles are long lived compared to pest flies. This is both strength and a weakness for their population. They may live long enough to make nests and brood balls to protect their young which improves their survival but that means as little as one generation per year. If that one generation experiences problems such as a lethal pesticide residue in manure the entire year is lost and there may not be enough beetles to over winter and repopulate the next year. Meanwhile, pest flies can produce many generations in one season, as many as one every two weeks for the common horn fly. Interruptions of their life cycle causes little damage. A handful of surviving pests can often repopulate in less than one season if not reined in by the ecosystem.

The differences between species in their reproductive behavior, their nutrient needs, their tolerance for weather and man-made chemicals and their rate of reproduction means that some are active when others are not. Diversity means that there is more activity in the pasture over a longer season. The livestock producer hopes that activity will mostly favor livestock with clean and abundant forage. For the livestock producer that means there will be some grasses to grow during the heat of summer and some to grow during cooler seasons. It means there will be some legumes to capture nitrogen and a few poisonous plants that animals avoid because they have better things to eat. It means there will be some beneficial insects and some pests. The hope of the herdsman is that the balance of the system will favor livestock and also not collapse during tough times of drought or flood but continue to provide forage at a low cost.

There are species of dung beetle for every climate and soil in the United States and they require little more than a non-toxic pasture and manure. Native dung beetles fed on wildlife dung before the introduction of livestock so they can survive without the presence of cattle or sheep. A few introduced species of dung beetle might inhabit the north central region because of reintroduction programs that ended in the 1980's or accidental introduction but there is little study in this area. Your local entomologist may know which species occupy your area. University archives may hold unpublished lists. In 1975 South Dakota State University published a list of insects, including dung beetles that had been reported and verified in South Dakota. It is titled "South Dakota Beetle Checklist" and is available online as one of the information products for this project grant at http://mysare.sare.org/sare_project/fnc14-977/ . In 1975 most of the commonly used modern pesticides were not yet available. Parasite and fly pesticides, if used at all, did not include most of the products used today. What remains of the original dung beetle population varies from pasture to pasture. Jacob Pecenka, MS under Jonathan Lundgren, PhD is currently researching dung beetles in north east South Dakota. So far it is clear that population size and diversity vary a lot from site to site.

Dung beetles' life cycles intersect both the nutrient cycle and the manure breeding pest life cycles. The beetles accelerate the nutrient cycle and slow down the manure breeding pest life cycle by reducing manure volume and changing its chemical and physical characteristics. Dung is rolled, chewed, made into brood chambers, carried down burrows made in the soil and actually consumed as food. Harmful organisms can find themselves in the digestive tract of the beetles. The activity increases the surface area of the manure fragments, spreads the residue and digests it into components useless to the pest community but more quickly broken down into plant available nutrients. A good reference on this topic is found at http://umaine.edu/blueberries/factsheets/insects/194-beneficial-insect-series-3-dung-beetles/.

The pasture ecosystem functions to produce forage for livestock and also to give livestock a fairly sanitary area to rest, eat and reproduce. The pasture is not a feedlot where machines come to haul away manure and the dead. Without the natural cleanup crew of scavengers, pastures would be full of manure and dead insects, mammals and birds dried in the sun and very slowly decomposing. Fortunately, a pasture is an ecosystem with scavenger functions filled by a number of participants, including dung beetles. Their contributions are referred to as ecosystem services. Waste will break down much faster if it is first physically divided into smaller particles which create thousands of times more surface area for bacteria and fungi. That is why dung beetles make such a large contribution to the fertility of pastures. By breaking dung pats into smaller particles dung beetles multiply the speed at which nutrients return to the soil and become available to plants. It is possible to quantify the fertilizer value that dung beetles provide by looking at the fertilizer value of manure. The nutrients in manure are not available to plants until chemically changed by microscopic decomposers. "Pastures, particularly long-term ones, are notoriously deficient in plant-available N, which may limit pasture productivity. Plant-available N (nitrate and ammonium) is produced by decomposition (mineralization) of organic material (plant litter, manure or compost)." From "Nutrient Management on Intensively Managed Pastures" For a detailed description of nutrient cycling from plants to grazers to manure to soil to plants again Alberta Canadian Agricultural Service has published a short guide titled "Nutrient Management on Intensively Managed Pastures". The fertilizer value of manure to pastures is calculated. The link to the publication is http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex12813 .

Because dung beetles start breaking up manure pats within hours and horn fly larvae need two weeks in manure it's easy to picture a race between beneficial dung beetles and harmful pests. Dung beetles do not compete with pests for food nor prey upon larvae or eggs. In the course of feeding and nesting the dung beetles aerate and cool the manure they leave behind. That makes the pat unhospitable to the larvae and eggs of flies, parasites and disease organisms. Dung beetles of different species have different activities they complete in dung. They consume and destroy oocytes while feeding in infected dung. Some roll dung into brood balls to house just one or two offspring. Opening one of these tiny balls of manure sometimes reveals one or two young looking like smaller versions of their parents. Burrows are dug by other species and dung may be carried down the burrow where eggs and larvae are tended. Pests that overwinter in dung, like the horn fly and some parasites are known to do, may find their winter haven disappearing beneath them. In the project area dung beetles were found active in late October. Even though some manure may remain after beetle activity it is less likely to produce pests and will be decomposed faster by microorganisms than it would if intact.

Dung beetles affect the cycles almost as soon as manure hits the ground but the exact result in any individual pasture is waiting to be discovered. One of the reasons these arthropods are making headlines is that even though the amount of research is small the important effects of the dung beetles' "manure management " on nutrient recycling and control of manure dependent pests is already proven to be very valuable to livestock enterprises. Scientific research on the connections between dung beetle life cycles and pest cycles in northeastern South Dakota where this project was located is just beginning.

Further details and calculations for the amazing amount of monetary value that these insects add to USA pastures every year are discussed in " The Economic Value of Ecological Services Provided by Insects" published in the April 2006 / Vol. 56 No. 4 • *BioScience magazine* Authors, John E. Losey and Mace Vaughan. The full text pdf is generously offered for free at this time at http://www.bioscience.oxfordjournals.org/content/56/4/311.full.pdf+html. Table 1 in the article shows total economic losses in the United States averted as a result of accelerated burial of livestock feces by dung beetles in millions of dollars. Averted losses in forage fouling total 120 million, nitrogen loss to the atmosphere from manure 60 million, parasitism 70 million, pest flies 13 million for a total of 380 million in losses averted every year. These are nationwide statistics so they include pastures and ranches that have already lost their dung beetles or have a small, struggling population. The rancher who has a full population of dung beetles stands to gain a lot more per acre than the nationwide average. Using the same calculations on a per acre basis for an individual ranch shows how profits can be increased and protected by increasing and protecting dung beetles.

The common farm management evaluation calculations undervalue the pest control provided by dung beetles. The benefit of a pesticide application is usually overvalued because it isn't measured on the ranch. Assumptions, sometimes wild assumptions, about fly and parasite control are used in accounting for the cost of pesticides while actual results vary. Labels are carefully worded not to guarantee specific levels of control. Northeastern South Dakota may have untapped livestock production increases that could be realized by saving and increasing dung beetle populations through more careful use of pesticides. When it comes to pest control an accurate evaluation includes more than the expected increase in livestock production minus the cost of the pesticide. The expectations for pesticides being used today were mostly created before resistance was a factor and also used a limited number of field trials from just a handful of locations in the United States.

Pesticide labels are mostly based on field trials in paddocks at research farms far from healthy rangeland ecosystems of this region so the cost / benefit of pesticides cannot be predicted from labels alone. Also, field trials do not include the fallout from common mistakes that happen on real ranches. The cost of the chemical is a simple entry into a spread sheet but the effect on the ranch ecosystem and the resulting actual costs are complex. The complex costs are nonetheless real. For instance, the effect of dung beetles on the parasite reduction in cattle pastures is accepted to be very significant, up to an 80% reduction, yet the loss of that 80% reduction isn't added to the cost of a pesticide application that kills dung beetles. For real life accounting any chemical that harms dung beetles must be assigned the cost of the "extra" parasites that survive because of fewer dung beetles. If dung beetles are prevented from reproducing the damage extends into future years when parasites can build up unimpeded by dung beetles.

Another cost that must be assigned is all the problems that ensue when a non- target pest develops resistance to a pesticide used on a different pest. Every time a pesticide is used potential resistance by any pest in the vicinity is a risk. For instance, horn flies have developed resistance to some of the chemicals used to control internal parasites because of repeated exposure. Resistance created by this incidental exposure usually comes as a surprise and an additional application of a different pesticide will then be needed. Extra labor for applications and purchase price of alternative chemicals can add up fast. Investigating alternatives can pay. A few manufacturers have begun to promote their products as dung beetle safe and the products probably are safer.

For instance; chemical control of horn flies using a macrocyclic lactone that is possibly effective on horn flies for up to 21 days and probably destroys dung beetles and larvae for 60 days may have an application cost of $3.00 per head including labor. The control of horn flies may allow the animal to gain an extra 2 pounds worth $2.50 in those 21 days. Afterwards, the horn fly population will recover faster than the dung beetle population and will have unlimited dung for its eggs and larvae. The horn flies that survive the chemical treatment could produce a new generation 100 times the number of survivors and then another generation in 20 days 100 times the size or 10,000 times the number of survivors. The dung beetles would recover very, very slowly. Their life cycles take a whole season or even years to complete and only a few carefully tended eggs and young are produce per pair. The loss of the dung beetle benefit must be considered part of the cost of using the chemical. If an 80% reduction in parasites is lost the cost is quite large. Calves carrying a heavy load of parasites will have reduced weights and less resistance to disease for months into the future. If a $3.00 application cost per head causes a severe decrease in dung beetles which causes an increase in old manure pats and provides more opportunity for calves to contact disease and parasite eggs in manure then the cost is far greater than the $3.00! Coccidian / Eimiria species are of major economic importance in cattle, sheep and goats. Groups of newly weaned calves carrying a heavy load of this microscopic parasite gain less and have higher death loss. There is no practical chemical control labeled for use at pasture and medications approved for calves in dry lot are only partially effective and always an additional expense. In contrast, dung beetles removing manure before the Eimiria oocytes become infective are excellent control, completely safe for calves and costs nothing.

"Dung beetle numbers are at a low in the U.S. so there is room to increase the savings by increasing dung beetles. Protecting or increasing dung beetles on individual ranches could increase profitability and avert losses. "

Horn fly life cycle, the dung beetle life cycle, and the parasite life cycle all intersect at dung. When dung beetles use dung it is no longer a haven for pests. Individual dung beetles work fast and if their numbers are high they will remove, dry and/ or cool dung faster than horn fly larvae can mature (10–14 days), than oocysts of coccidian can become infective (3-7 days) or parasite eggs and larvae reach their infective stage. While the pest life cycle is fairly short the dung beetle life cycle can be very long. Few species in north eastern South Dakota have been thoroughly studied. It appears that a dung beetle life cycle may be as long as three years. If there is a chemical application or other event that kills both beneficial insects and pests, then the pest population will recover much faster because it produces new generations at great speed. It is usually true that the beneficial insect life cycle is longer than the pest life cycle. Since it is longer, every generation is crucial. Interrupting the beneficial insect life cycle gives pests an advantage. See figure 1 for a diagram of how the life cycle of the dung beetle connects with nutrient cycling and manure breeding pest life cycles.

"Interrupting the beneficial insect life cycle gives pests an advantage."

Fig. 1 Rangeland is full of cycles that intersect at dung. Dung beetles consume dung as food and use it as nesting material interfering with the life cycle of dung breeding pests and speeding up the return of nutrients to plants.

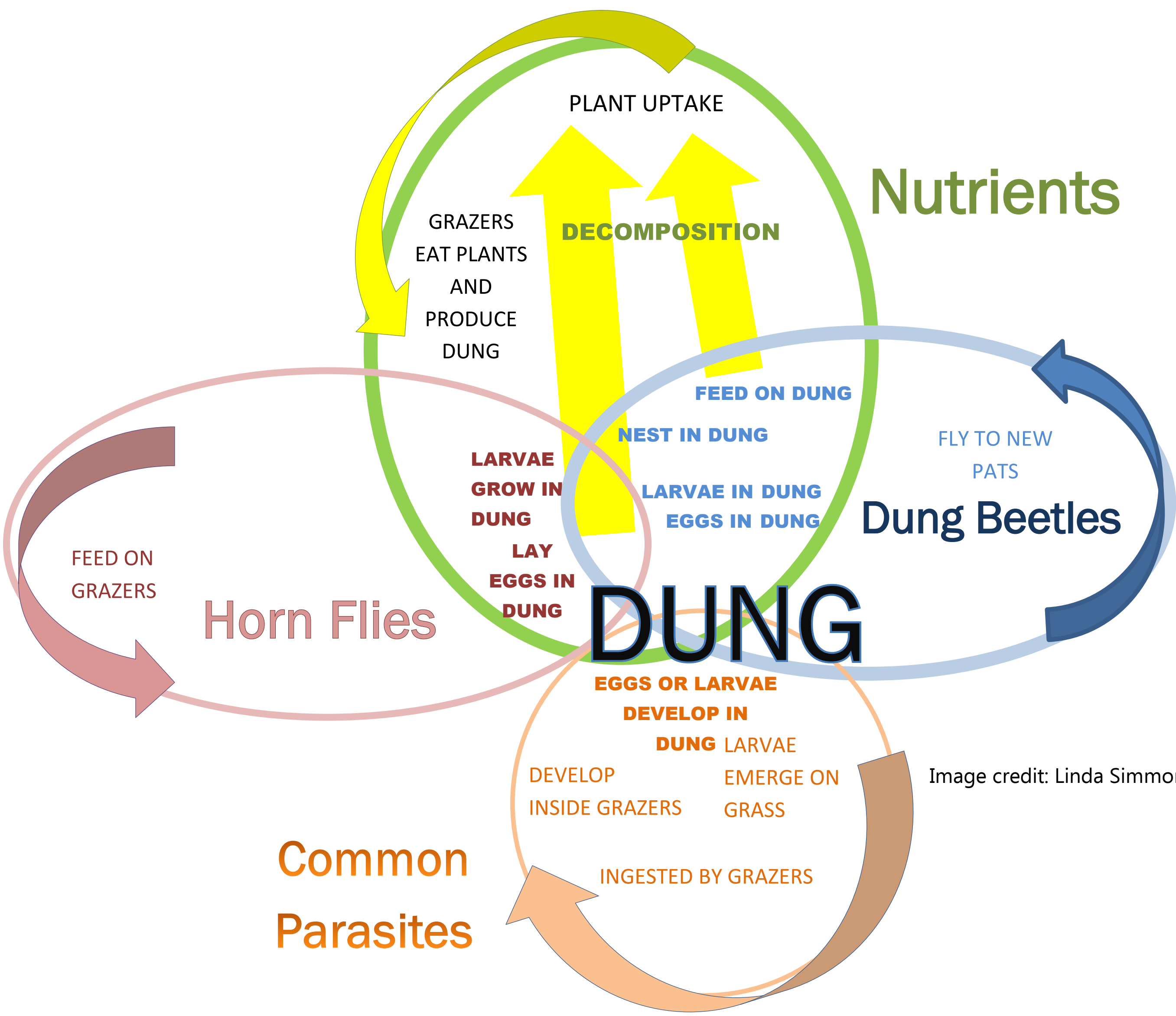

Image credit: Linda Simmons

Far reaching effects of management cross over from cycle to cycle. Graziers (one who helps livestock get their grazing done) have influenced the ecology of whole landscapes since livestock came to be. The modern grazier has a lot of options. There are stocking rates to consider, grazing intensity and duration, weed control, animal pest control, genetics, and forage nutrition questions to answer. There are many chemical pest control options. With so many possible answers from which to choose some must be wrong, costly and inefficient. As a general rule the grazier must deal with many unknowns and plan in a long time frame. It might be better in the long run to retain some valuable native insects and delay the onset of pesticide resistance than to try and keep calves 100% pest free. Industry claims may suggest that extra pounds at weaning may result. Unfortunately the extra pounds at weaning might not appear and if they do the cause might be some timely summer rain that increased forage quality rather than an injectable wormer or fly control pour-on. Rather than lose valuable long lived beneficial insects it might be better to be conservative with pesticides. Chemical application will rarely produce the desired result and only the desired result. Extinctions within the pasture ecosystem can be permanent whether it's valuable tall prairie grasses or helpful insects. Reintroduction is much more difficult than conservation.

The right rotation and stocking rate will favor highly productive grass species and keep forage plants healthy and high yielding. The rotation will reduce pests, especially internal parasites that breed or are transmitted at pasture. Most internal parasites of cattle, goats and sheep breed and are transmitted at pasture. Of special note is the group of microorganisms known as Coccidian or Eimiria species, the cause of coccidiosis. The oocysts of Eimiria require a brief period of development in fresh manure before they are able to infect livestock. Coccidiosis is of major economic concern to the beef cattle industry yet no chemical control is available for young calves at pasture which are very susceptible to serious infection and becoming carriers. Sanitation in pastures is the only practical defense in this case. Rotating animals to new paddocks in a grazing system removes them from their manure. That the manure won't be there when the animals come back is taken for granted, but it shouldn't be. If the dung is still there when the animals are brought back there is infection potential. If there are no dung community insects like dung beetles the manure will remain intact and a home for manure breeding pests. It will remain covering and fouling forage until weathered enough for bacteria and fungi to slowly consume it. The stockman would be wise to lengthen the rest period in that case to allow more time for manure to decompose. A healthy population of dung beetles provides more options in rotational grazing systems by removing manure before it becomes an infection source. The speed at which manure is processed into something non- infectious is a factor in how long before livestock should be returned to a paddock. Rapid manure breakdown also provides more plant nutrients. If manure break down is fast enough to stop the spread of diseases and pests plant nutrients are also provided rapidly for regrowth and the grazing rotation will function as intended.

The wrong rotation provides pests with a safe place to breed, brings livestock into more contact with infectious organisms and closer contact to pests and injures forage production. Slow nutrient cycling is a frequent plant growth limiter in pastures. The difference between right and wrong can be mostly due to not matching the length of rotation with the decomposition rate of manure. The life cycle of the looming pests and disease organisms is usually tied to manure and a grazing rotation system is also a manure management system. If manure is not being broken up and decomposed before the bad guys reinfect livestock the rotation can increase infection rates. Testing and making observations to determine which parasites and disease organisms are likely to be a problem, how their life cycle works and observing how fast manure ends it's infective stage are factors to consider in planning a rotational grazing system. Plant production requires nutrient recycling and the roots of the plant require respite from grazing in order to grow roots to access those nutrients. Plant production requires more than nutrients. Plant reproduction is essential so that there a constant number of plants in their prime are growing well. Management without consideration for the plants' needs can deplete the diversity and even the number of living plants. Seed production, beneficial insects and soil health are just a few of the things management can subtract. As years go by in a rotational grazing system manure cycling and root stores of the forage plants need care as well as the fences. Organisms that help plants produce include pollinators for seed production and predators of plant predators. Diversity keeps the pasture healthy. Beneficial insects are essential to a highly productive grazing system.

Resistance is the new deal. Inconsideration for the ecosystem as a whole has led to pesticide resistance. Resistance is now the rule rather than the exception because most of the active ingredients in pesticide formulations have been around for decades. The only way to get ahead of pesticide resistance is to know what active ingredients have been used on the actual pest population, which might include neighboring herds and know the pests that needs control, for example the common horn fly (*Haematobia irritans*) and know what controls are already acting or are soon to act on the pest. For example, the golden dung fly (*Scathophaga stercoraria*) and dung beetles (many species in the family Scarabidae) are biological controls of the common horn fly. Long term successful pesticide use requires elaborate management strategies. Rotating chemical families of pesticides is standard advice and valid, but it is increasingly not enough to control pests because the active ingredients available have changed little in decades. Non-chemical control requires less complex concerns or risks.

The following example makes the point. In the demonstration area the land produces an average of 1.3 AUM's (Animal Unit Months) per acre so it's economical to put in enough fences and water to build a rotational grazing system which was done in 2011 to 2013, before the project. Like many producers, I read the label on cattle mineral containing feed-through fly control and assumed it would control flies forever and damage nothing else. There wasn't a serious horn fly problem when I started feeding it in 2010. I thought it would increase the pounds of beef produced per acre. Weaning weights went up, but they may have gone up because of our new grazing rotation in 2011 or because of extra rainfall. Rainfall of just one extra inch is estimated to produce an extra 250 pounds of usable forage per acre and since rainfall varies so much from season to season no producer can judge the success of a practice without considering rainfall or other factors that usually go unnoticed.

After having severe losses from flies in 2013 and 2014 we abandoned some pesticides because they didn't work anymore. Prior to 2014 we did not keep track of fly numbers before and after pesticide treatments so we could not have known what level of fly populations we were trying to reduce and we could not have known what percentage of control any of the pesticides were providing. The failures of pesticides cost our operation more than the savings we achieved when the pesticides were working well. We didn't realize that we were risking catastrophic failures by forgetting about the biological controls that already reside in our pastures. We were at risk because we hadn't learned how to use fly traps and we had not been taking care of our dung beetles and natural fly predators. We damaged our dung beetle population by using injectable and pour-on pesticides as well, before making the connection between chemical residue in manure and beneficial insects.

> **"We did not keep track of fly numbers before and after pesticide treatments so we could not have known what level of fly populations we were trying to reduce and we could not have known what percentage of control any of the pesticides were providing."**

After experimenting with alternatives we found that rotational grazing plus feed through fly control did not control horn flies as well as rotational grazing plus the Walk Through Horn Fly Trap, described in later sections. It was also obvious that rotational grazing and phosmet (a phthalimide-derived, non- systemic organophosphate) did not control horn flies as well as the rotational grazing and the Walk Through Horn Fly Trap. Spinosad/spinosyn, which is no longer marketed as a direct application livestock product, provided excellent control the one time that it was used. It did require more man hours to apply than use of the trap and it's not labeled for fly control on livestock now.

Livestock choice can reduce the need for pest control. Most pest species and diseases do not transfer from one livestock species to another and changing the livestock species tilts the ecology of the pasture away from the old pests, but toward the new. Even though pests adapt that does take time and sometimes a whole life stage of a pest can be disrupted if the species of livestock is changed at the right time. If the life cycle of the pest or disease is known, changes can be made at the time when it's possible to disturb the life cycle. Removing the host of a pest just as it requires the host should be more effective than any pesticide event. "Know your enemy" is a good management strategy to plan the timing of practices.

Breeding livestock to be pest resistant has occurred since domestication. In the past the only two controls of livestock parasites were grazing management and genetics. Genetic resistance to parasites by livestock is an accepted fact but has been difficult to quantify and even harder to market. Resistance to horn flies by cattle is described in scientific literature as carrying fewer horn flies than adjacent cattle and showing that trait over a long period of time, such as two years. Amazingly, individuals in the same group have individual tendencies to carry more or less flies than the average. A difference between 20 horn flies to 450 horn flies was reported by Brown in The Journal of Animal Science in 1992. Research has been conducted on the topic for decades. Some producers have been breeding for resistance. Resistance to horn flies does vary between individual cows and there is evidence that it is a heritable trait. An example of university research on this subject is "Estimates of repeatability and heritability of horn fly resistance in beef cattle" by A. H. Brown, Carrol Dayton SteelmanZ B Johnson and TM Brasuell Department of Animal and Poultry Sciences, University of Arkansas, Fayetteville.
Journal of Animal Science (Impact Factor: 2.11). 06/1992; 70(5):1375-81.
Paying attention to the age class of livestock and grazing the most susceptible animals on the cleanest (least contaminated with parasite larvae) pastures is a strategy to reduce parasitism around the world. An excellent paper on parasite management in India, where parasites are active all year long, lists options for management of parasites with or without chemical pesticides. The techniques can be applied to any ranch and will work even better if dung beetles and other beneficial insects are around to do their job. A handy chart and description of grazing strategies to reduce parasite loads is found at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3793100/. ATTRA, a branch of the National Association for Appropriate Technology, offers a guide to a controlling parasites in small ruminants that covers many management topics that would assist cattle producers as well. The ATTRA site offers "Tools for Managing Parasites in Small Ruminants at Pasture" for free download at https://attra.ncat.org/attra-pub/summaries/summary.php?pub=415

Neighbor connections count. Management is thought of as isolated producers humming away individually but this is not the case. In Northeastern South Dakota the pastures are small compared to more western rangeland, usually less than 1 mile square. Neighbors and their livestock are never out of reach of each other's flies and dung beetles. Since dung beetles can fly up to a mile in search of dung and flies of several kinds are often wind blown over ½ mile this is literally true. An introduction of non-resistant flies can slow down the buildup of resistant flies, sometimes. When looking at what enters and exits the pasture ecosystem don't forget the neighbors.

Advantages of having neighbor's pasturing livestock nearby are 1.There is a chance of natural reintroduction of beneficial insects and native plants if the neighbor has populations and you have lost yours. 2. Your neighbor is more likely to understand and be capable of solving problems in cooperation if your neighbor also has livestock. 3. Knowledge and observations can be shared. A conversation with one's neighbors can enhance management. The issues of pesticide resistance should be shared issues. Exposure of pests to pesticides is the origin of resistance and knowing the history of pesticide exposure on neighboring land is priceless in predicting resistance and avoiding failed chemical control. Sharing records of pesticide use with neighboring managers is part of "CAREFUL CHEMICAL CONTROL" and benefits both parties.

Organic and artisan markets and diverse land use disfavor pesticides, successfully.
Not every land owner values production in terms of pounds of mainstream commercial beef. Today there are niche markets for beef, new knowledge about forage production and pest control being enhanced by a healthy ranch ecosystem, land owners that value resiliency and diversity over short term production, etc. Organic livestock production has grown every year since USDA certification began. Land always serves several purposes at the same time and a healthy, diverse ecosystem often has value in that case. Solutions and overall management strategies from these producers are worth a look from conventional producers on the other side of the fence. At the very least conventionally producers could co-ordinate their pesticide use to slow down resistance.

Pesticides have their Shortcomings.

Pesticide labels are generally researched and approved before resistance has developed in any of the pests listed as controlled. Wise chemical control always includes much more than complying with the label.

The percentage of control likely to be achieved is impossible to predict with certainty that is certain! A non-chemical control back up plan makes sense under today's conditions. An individual ranch where conditions are different and/or chemical resistance has developed in parasites and flies could have very different results than the label indicates.

Horn fly control by macrocyclic lactones (for example: ivermectin, abermectin) or pyrethroids was once consistently very effective. If a chemical application killed 95% of adult flies then the 5%

remaining would be likely to be resistant and so would the offspring of those flies. Adult female horn flies produce hundreds of offspring in 14 days if manure is available and temperatures are warm. The small percentage of the pest population surviving quickly recovers. Over the decades pest fly populations have carried more and more genes for resistance to a variety of pesticides. Unfortunately, the organisms that helped control the pests do not recover as quickly and sometimes not at all. Because they are not as abundant and do not reproduce as quickly, beneficial insects are often decimated by pesticides that only dent the hordes of pest flies. The horn fly, *Haematobia irritans irritans* (Linnaeus) has been exposed to a number of pesticides and now shows resistance to several. Resistance has shown up wherever pesticides are used. Exposure without 100% death rate allows resistant pests to thrive and produce a whole new "herd" of resistant individuals. Repeated exposure to an active ingredient increases the percentage of resistant individuals. When a substantial percentage of the population is born resistant a pesticide will fail. The major pest flies produce as many as 60 generations per year so just a handful of resistant flies can multiply into swarm even as a pesticide or two is being applied to kill them. Parasites of livestock have also been exposed to pesticides and have developed resistance. It just develops more slowly than it does in flies. Unfortunately, some of the active ingredients in fly control products are also used in parasite control products, doubling exposure and increasing the chance that resistance will develop. Macrocyclic lactones are commonly used for both fly control and parasite control. For that reason alone it is worthwhile to use macrocyclic lactones very sparingly and especially no less than 90 days before turn out to pasture. Pests are exposed to a surprising number of pesticides on most farms and ranches. This is one reason the recommendations given for rotating pesticides to prevent resistance may not work. If the parasite control chemical rotation is not coordinated with the fly control rotation the parasites and flies could very well be exposed to the same pesticide several times a season and several years in a row. That would be very conducive to resistance. If the neighboring livestock operations' fly pesticide rotation is not coordinated pesticide exposure is likely to overlap and if cattle are brought in carrying pests resistant to any pesticides used the whole process is sped up. On actual livestock operations in the north central region of the US where livestock operations are fairly close together and pests are abundant resistance and failure are inevitable. The rest of the world has not forgotten that pesticide use has risks and failures. The APRD (Arthropod Pesticide Resistance Database) web site compiles information from the U.S.A., Canada and foreign countries. The web address is http://www.pesticideresistance.org/index.php. The website is for public benefit and presents known resistance in insects. For just one pest of livestock, the common horn fly *Haematobia irritans,* here is the list of proven and scientifically documented pesticides to which it shows resistance.: Shown Resistance to Active Ingredient(s)BHC/cyclodienes - Unspecified In Literature, coumaphos, cyhalothrin, cyhalothrin-lambda, cypermethrin, DDT, deltamethrin, diazinon, endosulfan, fenvalerate, flucythrinate, ivermectin, methoxychlor, permethrin, pirimiphos-methyl, ronnel, tetrachlorvinphos Z-isomer, toxaphene . Horn flies travel with cattle and the wind so there

may be horn flies on your ranch that are resistant to one or more pesticides on this list even if you have never used them.
It is common to acquire pesticide resistant flies from neighbors and it is easy to grow your own. Most people who use pesticides definitely do so. Just one ear tag in left in after the killing dose of insecticide has worn down exposes flies in the whole herd to a low dose of pesticide. Low dosage or non-lethal dosage is a major accelerator of resistance in pests because it allows a few individuals with partial resistance.

Resistance can develop rapidly and not be detected. There are no reporting requirements so most cases of pesticide resistance go unnoticed or unreported. The operator will only see the early signs of resistance if records of pest counts are being kept. The percentage of control that wanes before full scale resistance causes failure varies. For one common chemical control of internal parasites in cattle a 100 percent reduction in fecal egg counts was expected before resistance. Less than 90 percent reduction indicates that there may be resistant parasites are present. Such a small change is no doubt going unnoticed on most farms. A change that subtle could only be detected using a quality laboratory and by testing at least 10 percent of the herd. Even with testing it is difficult to tell the difference between reductions caused by chemical pesticides or weather or naturally occurring biological control or just the life cycle of pests. Pesticide resistance could also be masked by reductions in pest numbers caused by the pasture ecosystem.

When a pesticide is labeled for multiple pests and multiple applications per year the chance of resistance developing skyrockets. Chemical Parasite control may be needed as cattle enter feedlots in the fall and it would be an economic shame to have created resistance to macrocyclic lactones by internal parasites from exposing them to macrocyclic lactones all summer in a futile attempt to control resistant horn flies. Even when careful chemical control is used resistance is considered a threat and it is increasing. “Worm anthelmintic resistance is entering the final phase, where nothing remains with which to control worms at a level commensurate with profitable animal production. In Brazil, for instance, moxidectin alone or in combination with other compound(s) has failed in numerous cases in sheep and goats, and in New Zealand combined treatment of goats with moxidectin plus a beNzimidazole and levamisole failed completely against Trichostrongylus and Ostertagia spp. Cattle follow closely behind, with a recent survey in Argentina indicating a prevalence of 55 % of worm populations resistant to ivermectin.” J.A. VAN WYK Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort 0110, South Africa stated in a Farm Corp lecture for The New Zealand Society of Animal Production. Because resistance by multiple pests to multiple pesticides is increasing, reducing dependence on pesticides increases the security of a farm.

In the vicious cycle chemicals don't kill dung beetles, people do. If used properly, today's available pesticides will be useful a little longer. Some active ingredients such as ivermectin are lifesaving vermicides safe for use in people. There is no "bad" chemical, only poor usage. To be fair, the effect on the fertility of pastures, the predatory insects and the rebounding of resistant pests and parasites was never part of the labeling requirements. It is the responsibility of the producer to consider the long term effects. There is limited information about the effect of various active ingredients on non-target species on the pesticide label, but it is still worth reading the label. The responsible producer is left with the job of determining the actual effects at home.

Dung beetles have a particularly slow rate of reproduction so they have a very difficult time rebounding. They are long lived for an insect but many species produce just a few offspring and care for them by making dung nests and tending eggs. When most of an entire generation is wiped out recovery is very slow. When an entire generation of horn flies is wiped out recovery is fast. The exact effect of pesticides on a pest is a moving target since pests develop resistance. The fast reproduction rate of pest insects helps them recover from a pesticide application much faster than most beneficial insects.

The harm depends on the pesticide active ingredient, the dosage, the type of application and the timing. The best animal husbandry practice for annual worming has always been to worm pastured livestock as they come out of pastures in order to reap the most benefit from the cost of the pesticide/ wormer. Reinfection from parasites in pastures obviously stops when livestock comes back to the winter dry lot. The recent practice of applying ivermectin for control of lice in cattle in the spring, then for flies at pasture in June and then again for parasites at pasture in late summer has no doubt seriously damaged dung beetles in the north central region just as it has in more well studied regions of the US. There are, of course, many pesticides in other families that are toxic to beneficial insects even when applied according to label and veterinary recommendations.

Common Practices endanger dung beetles. An excellent paper on the current conflict between marketing and conservation questions was published in the Canadian Journal of Veterinary Research in 2006. Here is the information needed to view a copy of the document online: Floate, K. D. (2006). Endectocide use in cattle and fecal residues: environmental effects in Canada. Canadian Journal of Veterinary Research, 70(1), 1–10. A quote from the article appears below.

> "Many synthetic pyrethroid chemicals used for external parasite control on cattle are toxic to dung beetles feeding on the dung of treated animals. Some macrocyclic lactone chemicals, in particular the avermectins, have an adverse effect on the development and survival of dung beetle larvae and can reduce egg laying in newly

emerged adults. Avoid using such chemicals on cattle, especially in spring, when dung beetles are first emerging." Put simply "– To keep the beetles you already have, avoid using, on your cattle, chemicals that are toxic to dung beetles. Such chemicals include most synthetic pyrethroid chemicals and some macrocyclic lactones, in particular the avermectins." (From State of New South Wales through NSW Department of Primary Industries 2007 ISSN 1832-6668 Prime fact 442 " Dung Beetles Working for You" Replaces Agnote DAI-102 Check for updates of this Primefact at: www.dpi.nsw.gov.au/primefacts)

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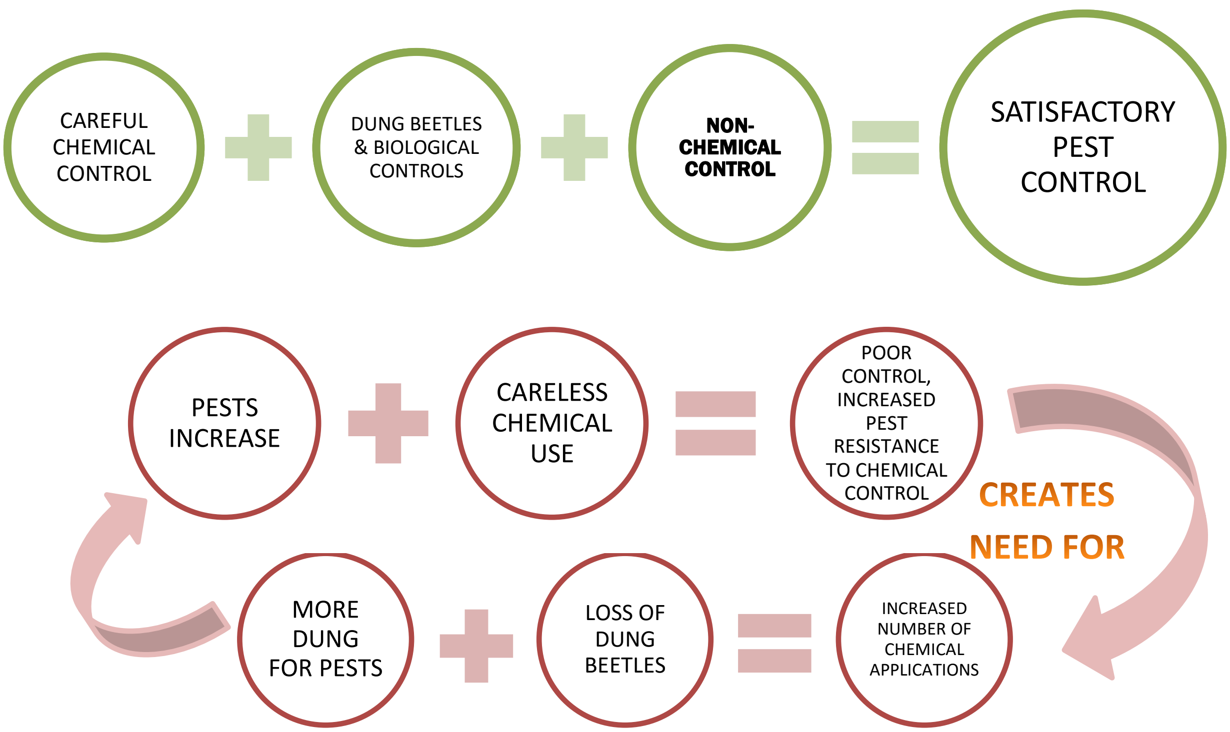
Each chemical and each commercial formulation varies greatly in toxicity to dung beetles and effectiveness against pests depending on its use. In general, systemic pesticides with residual effect are more difficult to use safely on the pasture ecosystem. However; addressing each chemical on a case by case basis is the only way to be wise. Resources to do so are scant. One of the most referred to papers on the toxicity of macrocylic lactones is Current Pharmaceutical Biotechnology, 2012, 13, 1004-1060 A Review on the Toxicity and Non-Target Effects of Macrocyclic Lactones in Terrestrial and Aquatic Environments Jean-Pierre Lumaret, Faiek Errouissi, Kevin Floate, Jörg Römbke and Keith Wardhaugh.



A Vicious Cycle image credit Linda Simmons

Fecal tests, pesticide application records, casual observations and scientific sampling of dung beetles in this demonstration project support the graphic above. An example of careless chemical control: The practice of applying chemical parasite control in the spring has far less value than applying chemical parasite control in the fall after cattle are removed from pastures. Applying chemical parasite control in late winter or early spring before turnout to pastures is definitely **"CARELESS CHEMICAL CONTROL"** and in this project case the parasite load was higher with **"CARELESS CHEMICAL CONTROL**" than it was with "**CAREFULL CHEMICAL CONTROL**" See fecal analysis results in Section Two for more details.

The main fly pest of pastured cattle is the horn fly, *Haematobia irritans irritans* (Linnaeus) and economic thresholds have been set at 200 flies per head. 200 flies may not be the economic threshold for everyone. It really is up to the herdsman to compare the losses caused by flies to the real cost of the treatment. While the number of flies is a valid observation the actual damage caused by flies when 200 can be counted varies beyond the pricing of chemicals and beef that occurred in the 1990's when this recommendation became common. Some animals are more valuable, some operators have higher standards of animal comfort, etc. There are many reasons for the individual rancher to create his/her own pest thresholds. Section Two contains a work sheet that can be used by producers to record fly pressure and animal behavior to develop their own standards.

> **"Failures due to pesticide resistance can have an astronomical cost compared to the price of one application."**

There are many unknowns: Reporting on Toxicity and impairment of reproduction on dung beetles has never been part of label requirements. It has not been studied much and concluseiv studies are rare. It will take decades before the full effects or all the common pesticides are known. Valuable populations of beneficial insects can be wiped out locally and regionally by common pesticide practices. The livestock production lost because dung beetles are not sanitizing the pasture and speeding up manure breakdown can be covered up by better genetics in the livestock and the extra inches of rainfall South Dakota has received since 1980 (NOAA data). Just one extra inch of rainfall produces about 250 pounds of extra forage per acre so animal gains that producers attribute to pesticide use could actually come from the extra forage being produced. The discoveries of very bad effects on beneficial insects from pesticides should be noted. Using those pesticides in a way that brings dung beetles into contact with residues in manure is probably not economical in the long run because losing the services of the beetles is costly in the long run. Actually receiving the production boost expected from pesticides is not as easy as it sounds! Failures due to pesticide resistance can have an astronomical cost compared to the price of one application.

Suggestions for chemical rotation in order to avoid resistance caused control failures are just suggestions. There is no guarantee that a particular rotation will work on your ranch. Using an active ingredient one year as follow up treatment might make that chemical useless as a rescue treatment under dire circumstances at a different time or destruction of beneficial insects might cause an increase in parasites. Either of these things can offset the benefits of pesticide application. This is where studying pests and beneficials on your own ranch can pay off.

Here is a case in point from parcel 1. In the project: Since 2012 the commercial cattle operation in this project has experienced nearly complete failure (less than 20% killed) from altosid and phosmet. The failure of feed through fly control contributed to a major pink eye outbreak that cost the operation $62.50 per head in vet bills and probably $30 per head in lost production. Fly populations exploded in three weeks coinciding with a pink eye outbreak. In parcel 1. feed through fly control in the mineral/salt mix had been used in 2011 and 2012 from April to October. Horn fly populations were low in 2011 but exploded in 2012 without a single day of missed chemical control. At that time the ranch wasn't being monitored for dung beetles or the speed at which dung pats degraded. If any of us had noticed an increase in old manure pats or had noticed the level of beneficial insects in the pasture there may have been a chance to change before spending$ 62.50 per head on pink eye treatments.

"Part of a pesticide program is accepting pesticide failure and changes in available products."

Previous treatments of cattle with macrocyclic lactones or feed through fly treatment (altocid) could have weakened our dung beetle population. Damage to the beneficial insects in the dung community would have left more manure available for horn fly and face fly breeding. I don't know exactly what happened because I wasn't marking dung pats and writing down how fast they disappeared. If slower breakdown of dung pats was noticed before the fly population exploded alternative treatments could have been brought into play sooner. Avoiding another incident of pesticide failure would surely increase profits and productivity, whatever the cause. In Section Two an easy method of marking and tracking the breakdown of manure pats is described. Reducing dung beetle populations or some predator of face flies and horn flies may have increased parasite loads by causing more infective feces to be left in paddocks. Whatever the reason the explosion of the pest fly population was spectacular and spectacularly costly. Feed through pesticide had failed. In 2013 we decided that we would be ready with a labeled pesticide, this time an organophosphate called phosmet. Two spray applications controlled horn flies well enough, we thought. We didn't take before and after fly counts to see if we had achieved 80 or 90 or 95% kill on horn flies. The control after one application seemed fine. The cattle were comfortable. We thought we had it licked. Even though organophosphates are somewhat hazardous and toxic to mammals their action on dung beetles when applied as a spray does not leave as much pesticide residue in manure as feed through pesticides. Phosmet seemed a good compromise and we assumed we could use it for two or three years before resistance showed up. It failed the very next year, spectacularly. We didn't need before and after fly counts to discover a poor kill. The only dead flies seemed to be the ones stuck to the cattle chute. Our mistake was costly because the fly population was exploding and the whole herd started swimming across a large wetland several times a day to escape flies and a cow became mired. Her injuries kept her lame and we lost her. We did have some Elector (spinatorem /spinosad based non- systemic spray) on hand and treated the cattle again. I counted flies before and 24 hours after treatment. That application achieved 98% kill. There were less than 3 flies per head. Spinosad is considered a selective insecticide that is less harmful to insects and aquatic life than many other pesticides. It won a Green Technology Award from the EPA in 1999 was registered as a pesticide in 2007 but its livestock formulation was withdrawn from the market about 5 years ago. That's another drawback of pesticide use for livestock producers. The market for a useful product might be too small for a company to keep that product on the shelves. New products are not coming to store shelves to resolve resistance issues. Part of a pesticide program is accepting pesticide failure and changes in available products.

This makes estimating the costs difficult and calculating the net benefits nearly impossible. Extra management time will be spent one way or another investigating resistance, finding new products, working livestock additional on the cross over exposure of parasites and flies to the active ingredients in pesticides used for each, creating yet another avenue for resistance to develop. If dung beetles are lost and dung pats start taking a year or two to break down instead of a month or two the pasture fertility will take a hit. A slight reduction in forage production per acre across a whole pasture is significant. Another problem to accept is changes in the ecosystem's ability to cycle nutrients for forage production. Once the services of the ecosystem are taken into cost accounting true value can finally be assigned. Real cost accounting will lay blame for costs and give credit exactly where it lies if the ecosystem of the pasture is understood. Not accounting for pesticide resistance and the loss of dung beetles is poor financial planning. If an extra 2 inches of rainfall has been soaked up by regional pastures in the last 25 years the ecosystem should get the credit for some of the extra beef per acre we have produced because more rain grows more forage in healthy ecosystem (150 to 250 lbs. per acre per inch of rainfall). Dung beetles can make sure the phosphorous, nitrogen and potassium are available quickly for forage plants ready to grow on that rain. It makes sense to keep the forage plants and the beetles healthy.

While no one would say that pesticides which stay on the skin or hair of livestock are safe for dung beetles, it is likely that pesticides which never touch the ground or end up in manure will probably do little harm. However; many pesticides are excreted in manure. Most wormer pesticides are excreted in manure to some extent. Many pour-on fly controls enter the skin and result in pesticide residue in manure. In general it takes very little toxic pesticide in manure to impair or even destroy dung beetles. Individual active ingredients vary in their residual and toxicity. Even with extensive use of pesticides there is no chemical remedy for every parasite and not every significant parasite appears on pesticide labels. Coccidian / Eimiria species cause important economic losses and there is no chemical control for use at pasture on the young animals that are most susceptible. The cheapest and best control is sanitation performed by the dung community insects. That is the dung beetles.

The toxicity of livestock treatment ingredients to dung beetles has received some study but there are many unknowns. An important overview of the macrocyclic lactones group has been published online by the AOSIS Open Journals titled Jacobs, C.T. & Scholtz, C.H., 2015, 'A review on the effect of macrocyclic lactones on dung-dwelling insects: Toxicity of macrocyclic lactones to dung beetles', Onderstepoort Journal of Veterinary Research 82(1), Art. #858, 8 pages. http://dx.doi.org/10.4102/ojvr. v82i1.858. There is also some news from the U.K. The work in the United Kingdom is very helpful to the north central region because the livestock and the climate have similarities. One of the most useful and easy to use web sites on dung beetles for producers is http://www.dungbeetlesdirect.com/Default.aspx. A guide sheet estimating the effects of common livestock wormers is published there at http://www.dungbeetlesdirect.com/Dung-Beetles/Info.aspx. It seems that very few manufacturers of pesticides have published information about how their products effects dung beetles. Non-governmental agency and government agency studies are underway but, typically, caution is advised when using pesticides. On my operation I will take more care to use systemic pesticides only if the livestock will be pesticide free by the time livestock at in the pasture. I will use only non-systemic pesticides at pasture for a last resort rescue of livestock and use non-chemical controls as a first line of defense against pest flies.

In northeast South Dakota the best pest control is usual sanitation, which is the specialty of the dung community insects. Dung beetles are the simplest, oldest, cheapest and safest aid to parasite and pest control in pastures.

PART TWO: "How to's" from the project

Study your own farm for your own profit and peace of mind. What do we need to know? Of course, we rarely know. If we knew what we needed to know before we knew it life would be easier. Every livestock pasture is different and every operation has different inputs to that ecosystem. For profitability and conservation goals each pasture makes its own contribution. There are many recommended scenarios that may not work out as expected. The scenario you are in is the one that counts. It's not easy to get the facts out of any ecosystem. The natural interactions of weather, soils and water and living organisms add all kinds of variables to our equations. Yet even a little study can bring to light major discoveries. Hopefully the discoveries can lead to a better bottom line and still take advantage of all the ecosystem has to offer. Studying your own farm can receive a jump start from SARE using a bulletin from the SARE learning center: http://www.sare.org/Learning-Center/Bulletins/How-to-Conduct-Research-on-Your-Farm-or-Ranch/Text-Version/On-Farm-Research-With-Livestock .

A small number of tests can be eye opening, even if they would not supply scientific proof. Like many livestock operators in South Dakota I had not taken fecal samples from animals in my herd. I assumed that labeled rates would kill my cows' parasites and that the parasites in my animals were the same ones on the pesticide labels. The few fecal sample analyses we sent to labs in the last 3 years have been utterly surprising. Our cattle and calves have appeared healthy and gained well and looked very nice and had great pregnancy rates. Their weaning weights have gone up every year for 6 years. We did not think our parasite program needed any adjustments. Calf vigor was better each year also and we discussed what practices may have given us the noticeable results. Pastures have many more important variables than feed lots so we knew that we didn't know for sure. We developed some informal scientific theories and tried to gather hard evidence. It was the autopsy report from a cow that died of clostridium at pasture that notified us that fall and spring pesticide type wormers applied and injected according to the label were not eliminating 100 % of the important cattle parasites. Study of parasites in pastured livestock leads directly to dung beetles; the original and still very significant pasture sanitation crew.

Example: Fecal Sampling

Starting in 2013 a few fecal samples were collected and turned over to the attending DVM veterinarian, John Campbell who is familiar with the life cycles of local parasites.
The first surprising thing I learned was that most cattle parasites were most vulnerable in the fall and were frequently destroyed by the cows' immune system or already passed out of their systems by spring. Also in my area, nearly all reinfection occurs at pasture. Most parasites spend part of their life cycle in manure. If conditions in the manure are suitable long enough for the egg, larvae or oocyte it will become an infective package on forage, waiting to be consumed by livestock. In some species a tiny intermediate host carries the package upward on the stalks of forage. For instance, a grass mite carries tapeworm larvae upward on blades of grass where it may be eaten by livestock. Parasites survive and move from the dung of infected cattle to new cattle when the forage touching undisturbed manure is eaten by new cattle. A small number of parasites overwinter in the north central region and they can be significant. Most of those species also need undisturbed dung at

some point in their life cycle. Where many animals eat contaminated forage around manure pats parasites are quickly passed through the whole herd. The immune system of the animal does kill many infective organisms but that ability varies greatly. Animals in their first year are much more vulnerable than older animals. That's one reason coccidiosis is such a serious disease in weaned beef calves that come from pastures heavily contaminated with dung and short grazed grass. Coccidian that cause disease are in every herd so when calve are constantly exposed to manure during their grazing Coccidian/ Eimiria numbers can build and cause serious disease. Disease organisms like parasites tend to persist using many patterns so there is no sense in guessing what the load may be unless some regular testing is done.

An instructional video including how to use fecal analysis and integrated pest management to control parasites is published on YouTube through a former SARE project. The link is: https://youtu.be/ZZQymZKe_hs . The video describes in great detail the principles of integrated pest management used for fecal analysis for parasites in sheep and goats. The principles of integrated pest management (IPM) also apply to cattle.

Before the project began the resident 71 cow herd and bulls (herd 2.) were poured with a macrocyclic lactone in November of 2013 while they were in the chute waiting to board the transport from pasture to dry lot for the winter. Fecal samples were taken in the chute just before the cattle were poured with wormer. Fecal egg counts taken from the manure of 5 cows the day of treatment showed zero parasites. 2014 fecal egg counts from manure in late July showed 4 out of 5 calves with a zero count. Note where the zeros showed up: Cattle poured with ivermectin in January, 4 months before being turned out in their pasture. Dung beetles were very active in that pasture in May through October. Was it a coincidence? On any individual ranch it takes a full scale investigation to know for sure. Since beef cattle off of pasture are most effectively wormed and the payback is highest when animals are wormed right after removal from pasture, it's common sense to use chemical pesticides that leave residue in manure as cattle are brought to dry lot for the winter and not when they are soon to be back at pasture. University and commercial trials of the chemical treatment show much better results for chemical control than the results from the demonstration would indicate. Things are different on a "real" livestock farm so the individual results will vary. That's why analysis for the parasite load of the actual animals slated for treatment is important.

Following is a table of the fecal sample analysis results from cattle in the project. In the pastures where dung beetles were observed the incidence of parasites was dramatically lower.

Date	sample ID	organism	result	chemical pest control history active ingredient	cattle class
10/1/2015	2104 Mark	Strongyle type	rare/significant	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	2104 Mark	Giardia	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	2104 Mark	fecal egg count	0 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	2430 Mark	Eimeria/coccidean	rare	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	2430 Mark	Giardia	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	2430 Mark	fecal egg count	0 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	3 s Mark	Strongyle type	rare/significant	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	3 s Mark	Eimeria/coccidean	light	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	3 s Mark	Giardia	heavy	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	3 s Mark	fecal egg count	0 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	638 Mark	Eimeria/coccidean	light	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	638 Mark	Giardia	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	638 Mark	fecal egg count	25 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	19 OD	Moniezia benedent	heavy	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	19 OD	Strongyle type	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	19 OD	fecal egg count	225 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	32 OD	Moniezia benedent	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	32 OD	Strongyle type	light	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	32 OD	fecal egg count	325 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	49 OD	Strongyle type	light	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	49 OD	Eimeria/coccidean	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	49 OD	fecal egg count	25 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	56 OD	Moniezia benedent	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	56 OD	Strongyle type	light	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	56 OD	Eimeria/coccidean	moderate	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	56 OD	Strongyle type	<200 epg	no beetles,dam only ivomectrin 2X march, april turnout	spring calf
10/1/2015	A H 16	Strongyle type	200 epg	no beetles, ivomectrin 2X march, april turnout	cow
10/1/2015	H 010	Strongyle type	400 epg	no beetles, ivomectrin 2X march, april turnout	cow
10/1/2015	H 7	Strongyle type	<200 epg	no beetles, ivomectrin 2X march, april turnout	cow
10/1/2015	H 94	Strongyle type	<200 epg	no beetles, ivomectrin 2X march, april turnout	cow
10/1/2015	N 415	Strongyle type	<200 epg	no beetles, ivomectrin 2X march, april turnout	cow
8/15/2014	calf 1	all test organisms	0	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
8/15/2014	calf 2	all test organisms	0	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
8/15/2014	calf 3	Eimeria/coccidean	rare	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
8/15/2014	calf 3	Strongyle type	rare	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
8/15/2014	calf 4	all test organisms	0	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
8/15/2014	calf 5	all test organisms	0	beetles, dam treated with ivomectrin Jan 2013,april turnout	spring calf
11/4/2013	cow 1	all test organisms	0	beetles, poured with ivomectrin Jan 2013, april turnout	cow
11/4/2013	cow 2	all test organisms	0	beetles, poured with ivomectrin Jan 2013, april turnout	cow
11/4/2013	cow 3	all test organisms	0	beetles, poured with ivomectrin Jan 2013, april turnout	cow
11/4/2013	cow 4	all test organisms	0	beetles, poured with ivomectrin Jan 2013, april turnout	cow

Once the results are in decisions about treatment can be made. Treatment with pesticides may or may not be necessary and the choice of pesticide and treatment can be targeted according to test results from the actual animals or group. A veterinarian who knows the life cycles of local parasites and pests is invaluable. Once the options are identified they can be screened for their activity against dung beetles. If harmful residues are likely to be found in manure from treated animals, turn out could be delayed until the manure no longer contains the residues. For dung beetles a better time to use chemical pesticides would be just as livestock is being moved to dry lot for the winter. That helps protect dung beetles by not exposing them to manure containing chemical residues. Many pesticides enter the tissues or digestive system of the livestock. Either the active ingredient or by-products of the active ingredient are eventually excreted. Some are excreted mostly in urine, some mostly in manure. Active pesticides in manure often affect arthropods in general and dung beetles especially. If chemical residue in the manure is no longer occurring then dung beetles are not likely to be harmed. The time it takes for manure to be free of residue from pesticides varies greatly between active ingredients and how they are applied. **Pesticide residue in manure can be a critical danger to dung beetles!** Each situation is different and the best treatment can be chosen only after looking at all the important needs and balancing them. This is called Integrated Pest Management, a frequent topic of SARES grants. Detailed descriptions of integrated pest management plans are available through the SARE website and the following links.

http://www.sare.org/Learning-Center/Fact-Sheets/Sustainable-Control-of-Internal-Parasites-in-Small-Ruminant-Production

http://www.sare.org/Learning-Center/SARE-Project-Products/Southern-SARE-Project-Products/The-Small-Ruminant-Toolbox

Example: Trial of the Missouri Walk Through Horn Fly Trap

Non-chemical controls are a very old and very worldwide idea. After all, the first pest control on livestock was non-chemical. Viewing reducing pesticides as a best practice can pay off financially and simplify management.

The Walk Through Horn Fly Trap designed in “Bruce Box” style by University of Missouri Extension personnel worked well enough on a Northeast South Dakota ranch to avoid pour on pesticides in the presence of a dung beetle population.

Performance of the Walk Through Horn Fly Trap built from University of Missouri plans in bulletin GS1195 was adequate to reduce horn flies on cattle by at least 100 flies per cow each time the whole herd was sent through the box. In this trial cows were only sent through the Horn Fly trap 4 times in the season. In a configuration where cattle walked through the trap more often it’s likely that the trap would control horn flies on many ranches in South Dakota that had similar biological controls as the demonstration pasture. The photo below shows calves waiting for their first trip through the Walk Through Horn Fly Trap. The brushing fabric has been removed because it frightened the calves at first. Later it was installed and served the purpose of causing the horn flies to leave the animals and enter the screen traps, an important function.

Calves waiting for their first trip through the Walk Through Horn Fly Trap. The brushing fabric has been removed because it frightened the calves at first. Later it was installed and served the purpose of causing the horn flies to leave the animals and enter the screen traps.

Horn flies in the trap

Plans for this Walk Through Horn Fly Trap are available in a set of University of Missouri Extension publications: http://www.extension.missouri.edu/p/MX1904C6 and http://www.extension.missouri.edu/p/G1195 . This trap was designed on the principles of horn fly behavior. After carefully observing horn fly behavior Robert D. Hall and David Lindell built similar traps and did university trials in 1986 and 1994-95 in the southern United States where horn fly pressure is much greater than northeast South Dakota.

In 2015 a trap using these plans was completed and deployed at parcel 1. with the red angus cows. The trap was not placed or used by cattle the same way as the southern studies. The weight, width and height of the trap was so great that it would have required a custom engineered wheeled trailer in order to move it between paddocks and water sources as it was placed in the two southern studies. Bringing cattle to the trap was not difficult in parcel 1. Cattle never had to walk more than ½ mile. The cattle were trained to the box in 4 trips, after that labor was minimal, 10 minutes per trip. Topical spraying of pesticides and/or inserting ear tags according to label recommendations would have been more labor and more stress on the cattle. Of course, these cattle accepted a trip to the corral because they had been taught that the corral was not a stressful place. They recognized a corral devoid of cowboys as a pleasant place to lick some salt or walk through an alley undisturbed. That's an essential part of using the Walk Through Fly Trap.
The control provided in this South Dakota demonstration was achieved by just an occasional walk through of the entire herd at times convenient for me to spend the 35 minutes it took for me to bring the cattle to the corral where the trap was installed. The whole herd was then taken through two corral pens and allowed to use the trap as the only exit into the corral rest area that held some growing forage all summer. I observed the cattle while they were enjoying the rest area. I think that the cows do remember the positive experience of losing their flies. I believe that if I start showing up when their discomfort from horn flies is at its peak for the day the herd will be waiting at the gate to the corral. I think it is likely that northern cows would learn how to walk through an accessible trap to remove their own flies once they have experienced the relief. I did not allow unlimited access to the trap because 1. The trap was too valuable to leave unprotected; 2. I wanted to preserve the forage in the corral rest area so flies could be counted easily; 3. Manure deposited in the corral can create bad footing for workers.

☺ YES, THE TRAP WORKS

Considering that cattle were not going through the fly trap several times a day as in the southern studies performance was outstanding. Cattle that walked through the trap did lose a substantial number of horn flies. It appeared that most cows lost roughly 150 flies or 50 % of their horn fly burden when the trap was working particularly well and fly burdens were about 300 flies per animal. A quick count of horn flies in the trap showed the actual number of flies caught in the trap was considerably less than the number of flies that were missing from cows according to counts of flies on the cows before and after walking through the trap. Regardless of that mystery just one trip through the trap by the entire herd did reduce the fly pressure and allowed for comfortable grazing immediately after exit from the trap, which was not occurring before the walk through. Calves seemed to come out of the trap with an even greater reduction of flies. That could be because the calves went through the trap as a group and that may have strongly encouraged their flies to briefly swarm upward and become caught in the louver shaped screed entrances to the fly prison chamber. Exactly how many flies were removed can be investigated in the future while the immediate result of stress free grazing was certainly an important result for animal production and comfort.

Counting the horn flies on the cows was done by randomly choosing 8 cows (10% of the herd) and counting patches of 25 flies as estimated from a few actual counts of 25 flies in a group on a cow. An easier, faster and more accurate way to count flies is proposed in the next section on recording flies and animal comfort behavior.

Fortunately for the demonstration, enough control was provided by the trap to be obvious. The trap appears worthwhile to build and use in most beef pastures in northeast South Dakota where cattle are easy to move and pastures are not over 2 miles square and horn fly pressure is moderate on the average. Leaving the trap accessible to cattle was not part of this project but in the three Missouri trials constant free access by cattle increased fly catch.

There are many possible modifications to make the Missouri Walk Through Horn Fly Trap more feasible and less expensive to build. For a new design to be successful it must exploit horn fly behavior. The Missouri entomologists' trap was intended to allow the horn flies to remain on the animal until in the depths of the trap where a brush contacted the animals back driving the flies into the air briefly. That provided the stimulus for the horn flies to leave the animal and fly toward the light. The opaque roof of the trap is important to direct the flies sideways into the catch louvers. A darkening drop at each end of the trap helped direct the Missouri flies into the louvers. This project's cattle were very wary of the darkening drop at each end and so it was removed. Between the animal and the sunlight coming in the sides of the trap is a screen chamber referred to as the fly prison. Slits in the inner side of the chamber along louver shaped screens allowed flies to crawl outward into the fly prison but not find their way back to the animal. The trap functions well as it was designed. Changes in the design might reduce the fly catch. There could be modifications that increase the fly catch and/or make the trap less expensive or easier to transport.
1. Horn flies must be on the animal long enough to enter the trap. 2. Horn flies must leave the animal once it is in the trap. 3. Horn flies must not leave the trap.
In 1996 the guide to building and using the Walk Through Horn Fly Trap was published and in it Dr. Hall wrote:

“Field studies conducted in central Missouri during 1986 indicated the trap produced roughly 50 percent control of horn flies when averaged over the season. This level of control was less than that afforded by insecticidal ear tags and some other treatments but maintained horn flies below the injury level of about 200 flies per animal. Similar results were obtained by David L. Lindell, regional extension specialist, during 1994-95, when field trials with two horn fly traps during the latter season averaged 40 percent control. “

Considering the impact of horn flies on modern beef operations keeping horn flies below 200 flies per animal with a single non-chemical control device is a major breakthrough. The team at the University of Missouri has performed an invaluable service. Their work is even more important in 2016 than it was in 1996. Pesticide resistance and the damage to the pasture ecosystem are more well-known and higher than in 1996. The net benefit of building and using a Walk Through Horn Fly trap is well into the positive for pastured cattle today.

Example: Nzi Traps

Horn flies plague cattle worldwide but many other flies in the group tabanids distress and create disease in all forms of livestock. The Walk Through Horn Fly Trap is unlikely to catch those flies. During the project only a negligible number of blow flies and stable flies were caught in the Horn Fly Trap. Sheep, goats and horses generally suffer more from tabanids other than horn flies. Losses can be significant. Sheep in the project area have died from blow fly distress when pesticide resistant flies could not be controlled. The Nzi trap attracts and captures a very wide variety of tabanid flies, proven by repeated research.

Nzi traps were developed to catch tsetse flies in Africa and thousands are in use there. The Nzi traps uses a specific shade of blue, pthalogen blue (alpha copper Pthalocyanine) . The trap has been well tested on three continents and it successfully traps flies of a wide variety. Two types of flies not captured very often in Nzi traps are horn flies and face flies. Stable flies, blow flies, horse flies, house flies and others are drawn to this trap. Stable flies and house flies were captured in the Nzi traps built for this project. The traps are not difficult or expensive to build. They require no ongoing bait or power of any kind.

An important paper titled Performance of the Nzi traps for biting flies in North America on the species and number of flies trapped by NZI traps in North America, especially Canada, was published in the Bulletin of Entomological Research (2006) 96, 387–397. The authors include S. Mihok1 *, D.A. Carlson2, E.S. Krafsur3 and L.D. Foil4 1388 Church Street, Russell, Ontario, Canada, K4R 1A8: 2US Department of
Agriculture, Agricultural Research Service, Center for Medical, Agricultural and Veterinary Entomology, 1600 SW 23rd Drive, Gainesville, Florida 32608, USA: 3Department of Entomology, Iowa State University, Ames, Iowa 50011-3222, USA: Department of Entomology, Louisiana State

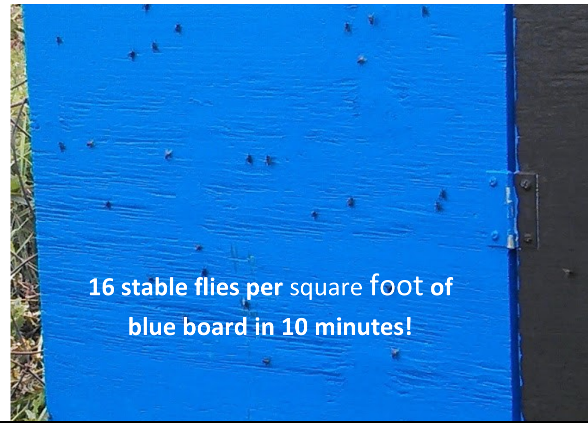
University Agricultural Center, Baton Rouge, Louisiana 70803, USA.

The question to study is will NZI traps catch enough flies be worth building and setting up on in your pasture or on your farmstead? This trap does not have drawbacks. It doesn't require pesticides of any kind. It doesn't use baits that can attract vermin. It isn't expensive. The only labor it requires is the building, setting out and disposing of flies. If an Nzi trap catches enough flies to prevent just a few dollars of lost production or saves the cost of just one pesticide application per year it is probably an economical addition to a livestock operation. An especially advantageous feature of the Nzi trap is that beneficial insects are caught unharmed and can be released anytime they are found in the collection vessel of the trap. The design of the collection vessel is very important to the success of the trap so if design changes are made they should be made carefully.

Nzi traps were not deployed long enough during this project to provide any data. Observations of how fast stable flies and house flies were attracted indicated that there is incredible potential as expected from scientific research on the traps. The design of the Nzi has been refined and tested by Steve Mihok and he has offered his research online at research gate and given permission to publish his detailed instructions in this document for public use. If a number of producers start to study use Nzi's and share their results it is likely that they will find the traps improve their livestock operations without any of the risks associated with pesticide use.

NZI traps can be easily built and they do catch stable flies and a number of other pest flies but not horn fly or face flies. Scientific testing of the NZI Fly Trap shows that it captures many species of North American flies. It has been tested for several years in Canada and results are fairly consistent. The NZI trap was developed to control tsetse flies in Africa. Plans for several early versions had been available to the public online but currently the French language website: http://www.tsetse.org/fr/Technol/index_french.htm and now are part of the annual reports found online for this SARE project. Reduced Pesticide Fly Control in Feedlots and Native Rangeland to Conserve Dung Beetles and Benefit Beef and Sheep Production, http://mysare.sare.org/sare_project/fnc14-977/. Search SARE project reports at https://www.mysare.org /search-projects/ for FNC14-977 Reduced Pesticide Fly Control in Feedlots and Native Rangeland to Conserve Dung Beetles and Benefit Beef and Sheep Production or navigate from the SARE home page.

Deviations from the Mihok Nzi trap construction instructions are likely to result in an unsuccessful trap. The insect eye perceives color different from the human eye and insect behavior is highly studied but difficult to explain. Substituting different hues for pthalogen blue are not necessary because retail paint vendors can now use Pantone pigments custom mixed with a minimum amount of white for durability.



Important tips: ONLY CERTAIN SPECIFIC SHADES OF BLUE attract flies well enough. White netting has been recommended but always use matt finish, not shiny netting or screen. The upper tip of the netting requires a fly holding area- often a plastic bottle. Flies should crawl up the tube of netting through the narrow neck of the bottle and find returning difficult. Make this bottle easy to remove otherwise emptying the trap is too difficult. Face the trap so it receives some direct sunlight. In less than 4 hours one trap in this project collected 387 stable flies on a cool September afternoon so have a fly disposal plan.

The NZI traps in this project were made of plywood, fine no see um mesh and painted with Benjamin Moore Brilliant Blue latex paint, because it was recommended as a very close match to pthalogen blue and black paint following instructions from a publication developed for USDA/ Agricultural Research Service by Steve Mihok, Ontario. A schematic of a cloth version of the Nzi trap is also shown at the end of this section. Nzi traps appear to be commercially available through http://www.rinconvitova.com/fly%20trap%20Nzi.htm. No warranty of effectiveness is implied but Nzi traps constructed according to the Mihok instructions have definitely been shown to catch many species of biting flies that plague mammals worldwide. Most of these species are controlled by pesticides only at impractical expense and labor. Nzi traps both attract and catch flies without moving parts, baits or electricity. The original pdf and ppt files published by Steve Mihok are now available on his Research Gate page and at . The plans and scientific research proving the fly catching abilities of the Nzi trap are also available there. Biting flies that do not stick tight to the animal, stable flies, house flies, green bottle flies, horse flies and many others are attracted to a certain shade of blue for which the technical name is pthalogen blue. Many other shades of blue have been tried but entomologists are in agreement that this shade is best. In the best scientific paper on the subject several commercial products were noted as having a close match to the shade of blue needed and this demonstration project used one of those suggested products, Benjamin Moore Brilliant Blue. Insects do not have favorite brand names but they do have a favorite color and the trap will not work without it!

- **Use exterior grade 3/8 inch plywood**; fill in any flaws with Polyfilla. This grade should not warp with time. It is a good compromise between cost, weight and durability. A thicker grade (1/2 inch) is also suitable, but a bit heavy. I do not recommend masonite (rots/warps) or 1/4 inch plywood (warps).
- **Catches of many biting flies are reduced by shiny features of traps, so use FLAT paint.** Only exterior latex paint has been tested so far; however oil-based paints should also be suitable. Apply a primer coat, and apply two further coats of paint.
- **The correct blue is critical.** An appropriate tint in the "Color Preview Collection" of Benjamin Moore paints is Brilliant Blue (#2065-30). Other brand names can be matched to this specific tint in paint stores, or on the web at **EASYRGB**. It is best to use a similar quality of black paint to avoid the need to repaint S/SW-facing surfaces. Cheap brands will fade badly after one season.

- **Recommendations for optimal cloth traps also apply to this format.** Hence, use white, highly transparent, ultraviolet-resistant, mosquito netting with only a minimal sheen; avoid using dark or very shiny netting. Experiments are still ongoing on the suitability of many other transparent materials.
- **Aluminum wire insect screening may be preferable** to netting for some applications, but I cannot provide advice on an appropriate material. The only product I have tested so far (thin, black wire mesh for windows) reduced catches of tabanids by a factor of two.
- **Materials will cost ~ US$ 50-70, depending on the hardware and paint used.**

- The trap is best completed where it will be set in the field. Consult the instructions for cloth traps on Setting a Trap and Collectors for the North for various options.
- I raise the body of plywood traps on four bricks or pieces of scrap wood to make it easier to trim grass throughout the season. Raising it off the ground will also keep the bottom edge of the plywood dry so that it does not rot in contact with the ground.
- The front wings must be fixed in place with small stakes as they are hinged and free to move in the wind. With 3/8 inch plywood, the weight of the trap is also not quite heavy enough for the body of the trap to maintain its shape in very strong winds. Hence, the edges of the plywood should be pinned or fixed in place in several spots. I move traps for experiments, so I simply pin everything in place temporarily. For a maintenance-free trap, it is best to bolt the wooden panels to small stakes driven into the ground.
- I use a T-bar + flexible plumbing pipe system at the back to suspend the cone. A long, and more substantial piece of wood for the back corner can also serve a dual purpose as both a back brace and as a post for another light piece of wood to suspend the cone.

- A completed, frame-based trap using nearly opaque blue and black 3/16 inch plexiglass panels instead of 3/8 inch painted plywood, with white polyester mosquito netting.
- The frame is simply set on the ground; the front wings are wired to a grooved metal stake driven into the ground. The trap is heavy, but can be carried. It has an inner transparent plexiglass shelf (out of view).
- Material substitutions like this are part of ongoing experiments. This exact blue is the industry standard colour Rohm Haas #2114, which is a good match to phthalogen blue.

Nzi Trap Materials
FOR 6 TRAPS

MATERIAL	QUANTITY	SUPPLIER	INDIVIDUAL PRICE	TOTAL PRICE
1/2" PLYWOOD 4X8 ft	7 BOARDS	LOWES	$28.47	$199.29
POLYFILLA (SPACKLE)	1 TUB	LOWES	$5.48	$5.48
PRIMER	1 GALLON	BENJAMIN MOORE	$49.55	$49.55
BRILLIANT BLUE (#2065-30) MATTE PAINT	1 GALLON	BENJAMIN MOORE	$78.99	$78.99
BLACK MATTE PAINT	1 GALLON	BENJAMIN MOORE	$78.99	$78.99
WHITE, HIGHLY TRANSPARTENT, ULTRAVIOLET-RESISTANT, MOSQUITO NETTING WITH MINIMAL SHEEN	13 YARDS	ONLINE FABRIC STORE	$38.85	$38.85
2" HINGES	42	LOWES	$2.58	$108.36
#6-32 FLAT SOCKET BOLTS	1 BOX (100 COUNT)	LOWES	$11.23	$11.23
#6-32 HEX NUTS	1 BOX (100 COUNT)	LOWES	$14.97	$14.97
NEW YORK WIRE 84" WHITE LINELA SCREEN FRAME - 5/16"	75'	LOWES	$3.92	$42.00
3/4" X 3/4" PLYWOOD POSTS	24'	HOME DEPOT	$0.67 / LINEAR FOOT	$16.08
METAL T-BAR	(6) 5' POLES	LOWES	$14.48	$86.88
10' FLEXIBLE PLUMBING PIPE	24'	LOWES	$2.48	$6.20
3/4" RIGHT ANGLE BRACKETS	12	LOWES	$9.96	$9.96
SPLINE	N/A	LOWES	$7.98	$7.98
SPLINE ROLLER	1	LOWES	$3.47	$3.47
WEATHER TAPE	1 ROLE	HOME DEPOT	$7.47	$7.47
				SUBTOAL $765.75
				$45.95 SALES TAX
				TOAL MATERIAL COST $811.67

Example: Learn How Fast Dung Disappears

Dung disappearance means both higher soil fertility and fewer parasites and pests. Faster dung recycling contributes to profits in those two ways. The profits from any pasture depend on the decomposition of dung. Forage plants need nitrogen, phosphorous, potassium and minerals that their roots can absorb from the soil. The amount of these nutrients is limited which limits plant growth. Livestock consume the forage and plants need nutrients again to regrow. The grazier cannot afford to have nutrients locked away in undecomposed manure. 90 percent of the nutrients consumed by livestock are deposited as dung which must be broken down and decomposed in order to complete the cycle. If the cycle is fast fertility will not limit forage production. Forage production in pastures is often limited by nutrients, which can be tied up in undecomposed manure. An entire cow dung pat in the project pastures could completely disappear in less than 10 days or it could last 300 days. That's how much the speed of decomposition can vary. Sometimes dashed hopes of regrowth in pastures can be traced to low fertility. The less available nutrients, the more roots must grow to find nutrients and plants that must use up energy reserves to grow roots to find nutrients have less energy to grow forage.

How is dung processed into smaller particles that allow for fast decomposition? The organisms responsible for changing the structure of dung pats are usually dung beetles. Different species of dung beetles have a variety of behaviors that physically spread dung into smaller particles and the digestive system of the beetles also chemically breaks down dung that they eat. Without constant breakdown of dung problems for livestock develop. If there is one measurement a busy rancher should try to take it's the rate of manure disappearance at pasture.

To find an accurate average rate a producer may need to mark about 10 pats every 3 weeks during the grazing season and go back weekly to see how fast the pats degrade and disappear. Weather will have a large influence as well as wildlife. Birds were observed tearing apart dung pats in search of seeds or insects. The activity varies incredibly from week to week and year to year. The more diverse the community of organisms that are active in manure, the more likely activity will continue under different conditions. Science is light years away from predicting the rate of manure decomposition from the content of the community so measuring the rate of decomposition directly is most accurate and also easiest.

Ranchers can also use their knowledge of manure break down to predict pest cycles. If manure stays in good condition for horn fly larvae for more than 14 days horn flies are likely to increase, since they need to live at least 14 days from egg to larvae in manure. Cooler weather that slows down decomposition usually slows down larvae development too but activity rates for each species vary with conditions. Temperature and humidity influence the speed at which pests and parasites develop so there is no preset goal for how fast manure should decompose or disappear in a pasture. The only thing that's sure is that faster is better. If manure is remaining a good home for manure breeding pests long enough for the pests to develop a pasture will have more pests. Of course that's bad and the operator who knows when manure is building up for pests can try to head off possible outbreaks. Sampling the manure for dung beetles can help make decisions about pest remedies. Some of the remedies can be moving livestock to different paddocks, bringing fly traps closer to the hatching area or physically breaking up manure if no helpful dung beetles are present. A feed through, pour on or injectable pesticide may be a tempting option but it might impede dung beetles that are trying to colonize the area.

Bits of the previous year's cow pats were easily found by looking in the center of 14 inch diameter spots of extra tall and extra green grass in mid-June. Because of the rotational grazing system it was known that the ½ inch bits of manure at the center of the spots were from the previous falls grazing cattle. The intense green color and height of grass in the manured spots could be seen from 100 yards away. Production was greater and earlier there without question. That provided incentive to study the rate of manure pat breakdown.

Several methods of marking pats were tried in order to record how fast they disappeared. Wire flags were disturbed by cattle and left wire in the grazing areas. Plastic flags were windblown. Neither plastic nor wire flags had a surface that held easily visible date markings. Using the GPS feature of a cell phone including photographs of the pats worked somewhat better but the numbered pats took from 10 to 30 minutes to find with all of those methods. Sheep dung would be impossible to find using the level of GPS precision that cell phones have. The system of phone GPS and plastic flags was too labor intensive and the flags were easily removed by livestock, wildlife and weather, never to be found again. The only practical markers are simple low cost white plastic temporary fence posts. The posts are designed and intended to be safe around livestock and they last for years. They are also easy to find if lost, leaving no debris behind. Ordinary black marker also faded away in the sun in just 3 weeks. Small dry pieces of dung pats can last almost a year in parcel 1 and may last even longer in other pastures so the marker ink should have a life of several years.

Only the final method worked. Tracking dung pat break down is easy using this method. Materials needed are very simple, safe for livestock and inexpensive. The easy to find point markers for manure pats are white plastic, temporary fence posts with a flat side large enough for writing dates. They are available where temporary fencing is sold. They cost less than $3 each and last for years. Permanent ink pens labeled as non-fading is required. Livestock ear tag pens are suitable, but all label warnings should be heeded. Non-fading construction pens are also available. It is exceptionally important to flag only fresh manure. Observing the animal defecate is the best way to know the dung is fresh. Cow pats have a surprising variety of appearances after a few days. Don't be deceived into thinking age can be judged by appearance. Weather notes, especially precipitation, are important. Finding daily weather records for your location may be more practical than keeping your own records but either of these will be very valuable when looking back at the disappearance records. Moist dung breaks down faster than dry dung, usually. Decide on a standard for calling pats "disappeared" because small bits of manure might be found in place over a year later.

In a rotational grazing system it might be more convenient to mark pats the day livestock are brought to a paddock where there is no old manure.

There is no way to know the age of a pat other than by marking it with a pat "birthdate". Several different markers were tried over two years and the only type found safe for cows and calves that also lasted long enough to be helpful were white plastic posts for temporary fencing. The smooth white surface accepted non fading marker to write the day the pat was created.

What happened to this cow pat? How long did it last? When was it laid down? Just write the pat's date down on a white temporary fence post (costing $2.29each) with a sun proof marker and you can easily observe the surprising process of dung dissapearance. Wire flags don't work in real pastures we found.

Biologically inactive pat on the left, dung beetle disturbed pat on the right. Pats are the same age.

FINDINGS: The appearance of pats did not relate to their actual age. Dung community organisms and the weather change the appearance dramatically so appearance does not give a single clue to age. In fact, marked pats laid down in May and June did not degrade into tiny particles as quickly as some pats laid down in July. Pesticide residue in manure could be the cause. One set of marked pats showed that a June 17th pat was still visible in September just 2 feet away from a July 21st pat that disappeared before Sept 2 in 2015.

Observing the rate of dung disappearance hasn't been done much so there are no standard goals, only anecdotes. From the experience of the demonstration project it seems that a baseline for each season of the year in each pasture is possible and changes in the baselines would give an early warning of horn fly out breaks and some clue to soil fertility and parasite and disease transmission during each season.

Example: Bug Lab = Berlese Funnel and Golf Cup Cutter

BUG LAB : the best available publication for producers on dung beetle study in South Dakota is credited to Jacob Pecenka, SDSU graduate student working under Dr. Jon Lundgren. Jacob's guide is available to the public through the final report for this SARE project. Titled Arthropod Importance is it posted online at http://mysare.sare.org/sare_project/fnc14-977.

A few tools and devices are used. It is important to pick up a consistent size sample of dung and be able to take the sample without disturbing the insects. In order for samples to be useful in calculating population size or density each sample of dung and soil should be the same or nearly the same in volume. Golf cup cutters come in one standard size to cut out a 4 inch diameter core 6 inches long out of sod and soil so they work well to take a 4 inch diameter 5-6 inch long core out of a dung pat including some soil underneath. Many dung beetles create burrows in soil and if the burrows are not included in the core, beetles will be missed. They are also fast crawlers and can escape through these burrows if the sampler takes more than a few seconds to operate the golf cup cutter. Keep the edges of the cutter sharp so cores can be removed from the ground in a few seconds, before beetles escape. The more expensive cutters have an ejection lever which makes getting the sample out of the cutter fast and easy. Immediately ejecting the sample into a collection bag also prevents beetles from escaping. A new, easy to use golf cup cutter may cost 300 to 500 dollars. Fortunately, the rest of this bug lab is very low cost

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Golf Cup Cutter

The Berlese funnel is useful for collecting separating many kinds of invertebrates from soil, dung, natural litter, etc. It has been in use since 1880 invented by Italian entomologist Antonio Berlese. Instructions for various versions can be found for free online. The version described here is similar to the type used in the ARS lab in Brookings, SD.

Berlese funnel and specimen jar

Bottom of Sample Holder

Instructions for a set of four Berlese funnels that easily accept cores from the golf cup cutter or given at the end of this section.

After the dung and 3-4 inches of soil is secure and labeled, the adult beetles need to come out . Rinsing the sample was tried in 2014 but, too many beetles escaped and the process took almost 2 hours per sample. Maintaining sanitation was difficult. The most used method by entomologist is to place the sample in a Berlese funnel and collect the beetles as they crawl down through the sample, through the 1/2 inch mesh into the funnel where they fall into the collection jars. The beetles and other invertebrates are moving away from the light and warmth and drying effect of the light bulb above the sample. Generally the organisms that come out of the sample are preserved in alcohol. It's not a common practice to try and keep the specimens alive, but of course that could be accomplished by placing a small amount of fresh soil covered by a small amount of fresh dung in the bottom of the collection jars. In that case it will be difficult to keep the dung beetles and hatching larvae of pests in the collection jars. Some may escape. Consider keeping the funnels in an area that can be secured with screens. Always play it safe and prevent fire hazards by keeping light bulbs away from flammable materials and prevent contamination by wearing disposable gloves. Dung and cloth screening can be flammable and must be kept a safe distance from light bulbs. Bacteria, parasites, fly larvae and other organisms in the samples are, hopefully, very alive so handle the samples carefully using rubber or latex gloves.

Between 1 and ten days organisms should start showing up in the collection jars waiting below the funnel spouts. Some insects may not leave the sample for 21 days or more. Part of the excitement of a dung processing laboratory is the unpredictability of what will show up in the collection jars. New discoveries about the organisms in your pasture are a sure thing. Have patience and make sure to label each core with the date and time of collection, the place it was collected and the name of the person who did the sampling. There probably will be eggs and or larvae left in the cores after all of the mobile invertebrates have crawled out. Returning the dry cores to their original pasture, destroying the cores in fire or rewetting the cores and incubating them longer are three options. Putting cores into different outdoor area than they came from could introduce new organisms to the new area because the dry cores are still full of living organisms, their eggs, their larvae or immobile adults. Both good and bad species could be introduced accidentally. Eh, dry dung has been used for household cooking fuel for thousands of years but that option is not recommended here.

Dung beetles are not always easy to observe. Each species has its own habits. They vary in size by species and stage of growth and habits. Some make burrows into the soil; most can fly and most are fast crawlers. A bug lab can be used just to learn about dung beetle behavior and to acquire some specimens to identify. For this project a set of 4 Berlese funnels were constructed in less than 3 hours using less than $ 50 worth of materials. If a producer can borrow or rent a golf cup cutter there is almost no cost to determining if dung beetles are present and how large the population may be.

Building 4 Berlese funnels for a small bug lab

Materials:

sturdy gloves, rubber or latex sanitation gloves, heavy aluminum foil for lids, 4 cotton balls, tin snips, wire cutter,2 sections of 24 inch long 6 inch diameter round aluminum duct work,1 grounded 4 light fixture rated for at least 40 watt bulbs or 4 fixtures rated for at least a 40 watt, enough ½ inch mesh wire to cut 4 7 ½ inch circles, light gauge is easier to work with than heavy gauge, 4 feet 14 gauge steel wire, non- flammable aluminum duct work tape, small hammer and 4 penny nail, wire or chain for hanging fixture,4 7 inch funnels (also called a 2 quart funnel approx. 7 ¼ inch diameter), 4 collection jars, denatured alcohol 90% or soapy water, a small standing shelf with an easy to cut top material to receive the funnels. An empty plastic lick tub works well. Optional materials : Ryker mount for mounting specimens, loupe 10 X, 20 X, insect identification key, tweezers, magnifying glass. If the lab is in an area where stray insects cannot be tolerated it's best to find a nonflammable screen house or build a screen box using metal screen to prevent any flies, beetles or other dung community organisms from escaping.

Step 1. Measure and cut duct work into 11-12 matching length sections.

Step 2. Punch two holes, 1 ½ inch from the edge and 10 inches apart into each aluminum section. The end with the holes in it is now the bottom.

Step 3. Cut 4 7 ¼ inch circles of ½ inch mesh, carefully measured and make a tight fitting lid with turned down edges for the bottom of each pipe section cutting the outer edge of the wire mesh circle in several places so it will fold over the lip of the tube. Use duct tape to securely attach the mesh leaving the two small holes exposed.

Step 4. Cut a 4 9 ½ inch pieces of 14 ga wire, bend each end of each piece into a 1/8 inch right angle then bend another right angle ¾ of an inch from the first one. The 1/8th inch hooks should fit into the small holes near the bottom of each tube. The 14 gauge wire now supports the wire mesh. Tape over the wire so that it remains in place.

Step 5. Wrap all of the sharp edges with nonflammable duct tape.

Step 6. Make some lids out of heavy aluminum foil for keeping the tubes dark and secured during transport.

Step 7. Cut holes in the stand top to accept the bottom 2/3 between ½ and 2/3 of the funnel depth, not counting the spout. For a 2 quart funnel a 5 ½ inch diameter hole is about right. A bead of caulk around the edge of the holes can help stabilize the funnels. Funnels are easier to clean if they remain unglued so it may be desirable to let the caulk dry before placing the funnels.

Step 8. Assemble all the parts as in the illustration and put wood blocks or adjust the stand so that collection jars are close enough to the funnel to keep specimens in the jars. Make sure everything will fit, including specimen jars below the funnel spout. If specimens are to be preserved then place an inch of 80 percent isopropyl denatured alcohol (keep out of reach of children). The alcohol is toxic. Soapy water can be used instead. In that case place specimens under refrigeration or dry mount them as soon as possible, before they spoil.

Step 9. Hang the light fixtures so the bottom of the light bulb is 1 inch above the open top of the tube.
Step 10. Go get some dung!
Step 11. Fill each tube with one 4 inch by 6 inch (estimated dimensions) sample. Try not to disturb the layers in the sample and do not invert the sample. DO NOT ALLOW DUNG NEAR THE LIGHT BULB. DUNG IS FLAMMABLE. Place in the stand, clear the funnel if dirt or manure falls through the mesh at and wait. Check the sample jar daily.

Once specimens are collected in the sample jars they should be transferred to permanent containers with labels. By counting the number of arthropods per golf cup cutter sample, comparing that to the size of manure pats and number of pats per acre an estimate of the insect population can be made. Good records make that possible.

Scientific Research using the Golf cup cutter and Berlese funnels was started during the project's second year and included parcels 1. and 2. Fortunately this research will continue through Blue Dasher Farms, Toronto, South Dakota. The USDA Agricultural Research Service laboratory in Brookings South Dakota was the site for analyzing the dung samples taken from the 338 ac and 80 ac demonstration pastures by entomology graduate student Jacob Pecenka in 2015. The sampling was part of a larger project that will be completed in 2016 or 2017. These might be the first dung samples to be examined for dung beetles in Grant and Roberts Counties since the 1980's! The species found in the 338 ac and 80 ac demonstration pastures are listed here:
Dung beetle diversity: Aphodius fossor, A. erraticus, A.matiganae, A. kirni, A. haemorrhoidalis , A.prodromus, A. granarius, Onthofagus hectate, O. pennsylvannicus.

The table below shows the totals from all of the 2015 samples from parcels 1 and 2.

	May		June		July		August		September	
	338 ac	80ac	338ac	80ac	338ac	80ac	338ac	80ac	338ac	80ac
Aphodius fossor	2	1	6	5	2					
A. erraticus	1		3	6	13	11				
A. matiganae	1	2	5	32	15	1	1	2		2
A. kirni		3	5	3	44	41	8	3	4	4
A. haemorrhoidalis	2	2	3	1	4	19		2	1	
A. prodromus	1	3	8	2	43	204	5	7	1	8
A. granarius	1	3	17	9	2		5			
Onthophagus hectate		1	1	4	1	3	2			2
O. pennsylvanicus	1	1	6	2		1				

The table above represents all of the samples collected in 2015 at parcels 1 and 2 which were processed in the USDA/ARS entomology lab in Brookings. For the season an average of 6 dung beetles per sample were found. The number varied greatly between seasons and samples. In this study each core was about ¼ the size of the average dung pat so an estimated 24 dung beetles in each pat, on average would be estimated. Each month a cow produces enough dung to support 32,084 dung beetles at the density they have been found in these two pastures. The exact number of dung beetles needed per pat to prevent pest breeding is not known and certainly varies.

Specimens Ready to be Identified Photo credit: Jacob Pecenka.

This is how many dung beetles just one core from the golf cup cutter can hold! Should we be finding this many or more in healthy pastures? Photo credit: Jacob Pecenka

Experiences from the months of the SARE grant period showed the usefulness of some simple tools to shed light on the dung beetle community health and the pest fly population problems. Knowing about the activity of these two types of insects could give managers new insight to keep their land healthy and reach their production goals.

Economic goals are of primary importance. Most grassland is part of a livestock operation. There are some surprising considerations involving dung beetles and pests. There's wide acceptance that dung beetle services benefit livestock operations through parasite control, sanitation and nutrient recycling. The benefits of dung beetles are huge. One of the reasons these arthropods are in the news is that even though the amount of research is small the important effects of the dung beetles' "manure management " on nutrient recycling and control of manure dependent pests are almost always found. An excellent reference: Fiene, Justin G. "THE BENEFITS OF DUNG BEETLES TO CATTLE PRODUCERS." Printed in Beef Today Magazine is available through BEEF TODAY.

Example: Easy Fly Records

Identifying exactly when flies, especially horn flies, are about to become a problem is difficult. How many horn flies are too many? The populations of horn flies in our area fluctuate wildly and can go from a moderate level to a high level in 2 weeks.

There is a standard recommendation that 200 horn flies is the threshold level at which it is worth the rancher's time and money to treat flies. That is a good economic threshold when it was set over 20 years ago. Since cattle prices fluctuate and fly control practices have different price tags the real economic threshold is different now. The threshold may change with the season too. Horn flies do not annoy the cattle when temperatures are low so 200 flies that are slow moving because it's 40 degrees F for half the day do not cause the same discomfort as 200 flies really enjoying an 80 F afternoon in July, biting cattle and laying eggs in warm manure. Female horn flies only leave the cow to lay eggs after they have bitten her to drink the blood meal they must have before laying eggs. The eggs number in 50 to 200 eggs per female and she lays them only on fresh manure pats. In about 10 days the eggs hatch into larvae and grow into flying adults which are ready to breed in 2 or 3 days. Horn flies can produce and entire new generation in 10 to 20 days. Given the number of eggs per female the horn fly can increase its population 10 to 100 fold in 10 to 20 days if conditions are right. 50 flies per cow could turn into 1000 flies per cow in 14 days. If dung beetles, the weather and natural predators are not sufficient the cattleman needs to intervene in the fly life cycle.

It would be ideal if the intervention did not destroy the beneficial insects that usually hold down horn fly numbers. It would be ideal not to spend extra labor and cash on unnecessary interventions.

To assist the livestock manager in recording pest fly pressure so he/she can use the records to get clues as to when the population of flies requires action. Estimating the number of horn flies per cow seemed to be a very inconsistent way to predict animal discomfort the way it was used in this project. Making estimated counts of flies on cows at different times of day and on different individuals every time was not very precise. It was noted that less than 200 horn flies per cow could sometimes interfere with grazing but sometimes 400 flies per cow did not. That may have had something to do with the biting behavior of the flies. It could turn out that noting the level of animal annoyance along with fly counts might give a warning that a large number of females are getting the blood meal they will soon use to lay eggs. A consistent way of recording observations is needed so the operator can learn from the observations and use them to predict when it's time to take some action.

A more accurate and precise method might be to take standard photographs of the same individual cows before and after the fly trap. A back tag on each hip of the selected cows would make it feasible for one person to quickly take photos of each side showing both the animal ID and the flies in high resolution. Flies could then be counted accurately in the lab. The photos would provide a backup record.

Recording behavior of the livestock might be a more direct way to determine pest fly thresholds. After all, the cattle know when flies are a problem so it might be worthwhile to observe and record some animal behavior along with fly numbers. A record sheet with room for both follows: personal records like this are useful when taken over a time period of a year of more. Notes can predict the need for a treatment and clarify how well a treatment worked. Treating with pesticides and not going back to carefully check the results is a big mistake. Determining the kill percentage is the only way to be for warned of growing pesticide resistance on your ranch. If even a small number of horn flies escape pesticide treatment resistance is likely to be present. The far less risky, non-chemical controls should also have follow up so the producer can plan to do more to stop the next horn fly expansion.

Date: Time of day: Weather:

FLY COUNTS: Likely to see horn flies on cattle, blow flies or nose bots on sheep, species is important

Estimated average per animal ____________Highest_____________ Lowest___________

POSITIVE BEHAVIORS: WHAT PERCENT OF HERD IS DOING THIS NOW?

Laying down______________Cudchewing_____________Sleeping_____________Grazing_____________

SIGNS OF STRESS:

Runny eyes________ Tail Swish per minute______ Head Swinging _______Stamping_______

Yarding__________Wading___________Milling____________Stampeding___________

Conclusion

The ecosystem provides the forage and sanitation and cycles nutrients in pastures. Three things of staggering importance where grazers live: 1. Dung beetles are a positive for any ranch, reserve, recreation area, public or private grassland 2. Pesticides, including the most commonly used sheep, cattle and horse wormers, are known to decimate and even destroy dung beetle populations in entire pastures 3. Pesticide resistance can appear suddenly allowing pest populations to bloom. So, it is logical to rely first on non- chemical controls by finding and testing many types of non- chemical controls to maintain a good balance in the pasture ecosystem. The time and place for pesticides with action on dung beetles is after the cattle are on the truck to the dry lot, away from the beetles.

Too many livestock operators, including myself, have been treating with pesticides and not checking to see if a few resistant flies have survived. That mistake can lead to repeatedly applying pesticides to populations with resistant flies until suddenly the lion's share of flies are resistant. Partial control leads quickly to pesticide resistance. Pesticide resistance leads to failures. Both partial control and pesticide failures are costly and risk damaging beneficial insect populations. Resistance is also definitely out growing new chemical solutions.

Beneficial insects, especially dung beetles have been preventing population explosions of pests for eons. They are as much a part of a healthy productive pasture ecosystem as the sunlight and the rain. They not only help maintain balance in pest numbers but also speed up nutrient recycling by breaking up dung. Their services have great monetary value. They work away mostly unseen until destroyed by pesticides. Then they can be lost along with all the benefits they provide. There are approaches to pest control that leave beneficial insects healthy.

> *"Beneficial insects, especially dung beetles have been preventing population explosions of pests for eons. They are as much a part of a healthy productive pasture ecosystem as the sunlight and the rain."*

There are alternatives to pesticides that work well in northeastern South Dakota, the area of this project. A few easily used tools for pest control and research are available. Modern versions of The Walk Through Horn Fly Trap and the Nzi trap were both developed under cooperation with public universities or government and plans are available to the public for free. See links in this report and the online NC-SARE reports for project FNC14-977.

Producers have the most to gain and the most to lose from their own pest control choices. Long term managers must make the wise choice because they have the incentive that vendors, veterinarians and temporary owners do not have. No university study of dung beetles on area commercial ranches has been published during the last 20 years so producers investigating their own land can greatly contribute. Only individual ranchers who know beetles have any idea if dung beetle services to the rangelands are still taking place in most areas of South Dakota. Fortunately, the research by SDSU/ ARS (USDA Agricultural Research Service) is continuing under NGO (non-governmental organization) Blue Dasher Farm, Toronto South Dakota with Dr. Jonathan Lundgren and Jacob Pecenka.

Some pastures with a history of extensive summer pesticide use appear to have no dung beetles. In three years of observation dung beetles were never observed in the 160 ac parcel 3 of the project, while they were found often in parcels 1 and 2. The same could be true for many pastures in the north central region. Flies and parasites have not disappeared, even where pesticide use has been extensive. In this project livestock pastured in parcel 3 showed a heavier parasite burden than when pastured with dung beetles. The cattle in parcel 3 were the same herd that had shown a very low parasite burden when pastured in parcel 1 the previous years.

Non- chemical control of pest flies has the lowest risk. A lot of unknowns exist when it comes to pasture livestock management. The pasture ecosystem has fast developing features and slow developing features that vary from pasture to pasture but affect livestock production and the costs of production greatly. Pesticides raise the risk of throwing the pasture ecosystem into a higher cost lower production phase. Caretaking at the points in the ecosystem where cycles intersect helps protect profits. That is **"Don't Cross Intersections without Looking Both Ways".**

The grazier has the most at stake. The veterinarian and the salesman will not suffer from the loss of dung beetles like the manager of the cattle at pasture. When dung beetles are not around to reduce pest flies and reduce parasite infections the livestock operator has a hole in his/her pocket. Noticed or unnoticed, no one reaps the benefits like the operator and no one takes the loss like the operator.

There is value to commercial livestock production in protecting beneficial insects by using non-chemical pest control methods and possibly careful chemical controls but never careless chemical controls.

Who is going to clean up all that manure?