White, Black, and Grey: The Role of Human Perception in Grasshopper Management Strategies

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Abstract

Grasslands are declining worldwide due to human conversion for settlement, agriculture, and rangeland. Grasshoppers are an important component of grassland ecosystems, however land use changes put them in direct competition with humans for resources. In the US, on a yearly average, 2 million acres are treated with pesticides at a cost of $5 million. This does not include the externalities to non-target organisms and human health, which can be as high as $1.76 million yearly. The USDA-APHIS program has invested millions of dollars to reduce the use of pesticides. Alternative control methods include, controlled grazing, prescribed fire, and mechanical control. These methods are not commonly adopted by land managers. The reasons may be due to lack of education and also the social perception of grasshoppers. A survey was conducted in Fremont County, WY to determine how social perception related to control methods and what information sources land managers relied on. The results showed that grasshoppers were largely viewed as negative or neutral by both land managers and non-land managers. Land owners who were impacted by grasshoppers had a slightly more negative view than those who were not impacted. The solution to this ecological and economic dilemma may be to provide true education to land managers in the form of a workshop.
Introduction

Grassland ecosystems cover 30% to 40% of earth’s land mass and are found on every continent except Antarctica (Branson et al. 2006). In the United States grasslands are found across the 17 western states and are of important economic value. Worldwide, up to 99.9% of historic grasslands have been converted by humans to use for settlement, agriculture and grazing land (Samson and Knopf 1994). The native ungulates of North America have been replaced by cattle, altering the ecosystem. Rangeland covers more land area than cropland in the U.S.A. and is the environment that puts grasshoppers in direct competition with herbivores of economic value, therefore this paper will focus on rangelands within the U.S.A. Rangeland covers 312 million hectares of land in the U.S.A. (NRC 1994). Along with the loss of natural grasslands comes the decline of biodiversity. Grassland bird species have shown dramatic and widespread declines ranging from 24-91% (Samson and Knopf 1994). Insect herbivores such as grasshoppers (*Orthoptera*) are a natural component of grasslands and are also found on every continent except Antarctica (Seergev 1997). The decline in grassland bird species has been shown to have a positive correlation to the increase in grasshopper densities (Bock et al.1992). Population outbreaks of grasshoppers can be of economic concern, especially on rangelands where they are in direct competition for livestock forage. Grasshoppers cause an average of $1.25 billion (2005 dollars) a year in lost forage that could be fed on by livestock (Branson et al. 2006).

When land managers (farmers and ranchers) are faced with economic losses from grasshoppers the conventional choice is to spray pesticides. The USDA-APHIS program pays for 1/3 of the cost of federally supported spraying, and the land owner pays the balance (USDA-
APHIS). During one outbreak year 8 million ha were sprayed with 5 million liters of pesticide, at a cost of $75 million (Lockwood and Lockwood 2008). Current pesticides in use are not target specific and have been shown to contribute to the decline of bees (Tuell and Issacs 2010). Given the high cost of both damage and pesticides; it seems that a change in the approach to grasshopper management is warranted. Non-conventional or cultural practices can increase the overall health of the ecosystem at a minimal cost to land managers. J.A. Onsager (2000) conducted a study that showed grasshopper densities could be 3.3 times higher in season long grazing sites as they were in rotational grazing sites. Several studies have shown that prescribed fire can decrease grasshopper outbreaks (Branson et al. 2006). These studies and many others have shown that there are alternatives to pesticides.

How and why land managers decide on grasshopper management practices has not been the subject of many studies. Yet without this information, how can modern pest control agencies best frame all the available options for grasshopper control? Does the social perception of grasshoppers by land managers influence their control practices? If land managers view grasshoppers as a natural part of the ecosystem, are they less likely to spray pesticides and use cultural practices (controlled grazing, prescribed fire, etc.) that are less environmentally damaging? Conversely, if land managers view grasshoppers as pests or as invasive species are they more likely to rely on pesticides as their primary method of controlling grasshoppers? To address the relationship between social perception and grasshopper management practices a survey of individual landowners in Fremont County, Wyoming was conducted. The goals of the survey in this thesis are to: 1) better understand how social perceptions influence grasshopper management practices, 2) determine where land managers acquire information that can influence their social perception of grasshoppers and methods for their control, and to 3) conduct a
literature review to assess the benefits and costs associated with conventional (pesticide reliant) and alternative methods for grasshopper control. The long term cost of using pesticides may far outweigh the benefits (Branson et al. 2006). As a result of these findings, educational materials made available through pest control agencies may need to be refocused to provide land managers a better understanding of the role grasshoppers play in the ecosystem and the benefits of alternative control methods.

**Background**

**Biology of Orthoptera**

While the taxon Orthoptera is typically clumped into one by the public, there are several distinct differences between grasshopper species. This order includes more than 400 species of grasshoppers (Order: *Orthoptera*, Family: *Acrididae*) in North America alone. The typical lifecycle is univoltine, creating one generation per year. Females lay eggs in pods containing 2-200 eggs and can produce between one and six pods a year. The females of most species prefer undisturbed and open ground to lay eggs. They dig a few inches into the soil and excrete a frothy substance that surrounds the eggs and protects them from predation and cold winter temperatures. A few species lay their eggs on grasses or forbs. In most species the egg develops into an embryo until cold winter temperatures cause it to enter into diapause. When temperatures warm the embryos finish development and hatch in the late spring or early summer. Typical grasshoppers require 150 day-degrees from the end of diapause to hatching. They emerge as nymphs and undergo incomplete metamorphosis. From nymph to adult grasshoppers pass
through four to six instar phases, during which they molt their exoskeleton. During the final
instar phase they develop wings. Adult females have a 1-2 week preoviposition period that
includes mating and internal development of eggs (Pfadt 2002). During the nymph stage they are
very susceptible to cold and heavy rains. Growing degree days can be used to predict hatching of
nymphs. Grasshoppers are ectotherms (external regulation of temperature) and as such
temperature and rain can be used as good indicators of populations. Out of the 400 species found
in North America only 10-15 are considered pests of economic concern (Lockwood and
Lockwood 2008).

Feeding habitats

While some species are monophagus (feeding on a single plant species), many are
polyphagous (feeding on many plant species). This is an important distinction in recognizing how
grasshoppers affect rangelands and crops. One species that is considered a pest is *Melanoplus
bivittatus*. This species is polyphagous and feeds on forbs, grains and corn. Another pest species,
*Melanoplus sanguinipes*, is also polyphagous and is known to feed on many plant species, from
grasses to grains to fruit and weeds. This species is migratory and responsible for most of the
economic damage in the USA. Geophilous (ground-dwelling) species only feed on plant material
felled by other grasshoppers and dead arthropods (Pfadt 2002). *Hesperotettix viridis*, while
polyphagous, feeds on noxious rangeland weeds that can be poisonous to livestock (Branson et al.
2006). This species may have only attracted study due to its economic benefit. A literature
review conducted by R. J. Dysart (1995) classified 65% of grasshoppers (in N. America) as
innocuous or of no economic importance. Only 1.2% were classified as beneficial or possibly
beneficial. There is likely many other species of grasshoppers that provide direct ecosystem services that have gone unnoticed or unstudied.

**History and range**

Throughout recorded history major plagues of grasshoppers, locusts, and Mormon crickets have periodically affected the livelihood of people on six continents. When Europeans settled in North America they brought the cultural biases of Biblical plagues with them. The Rocky Mountain grasshopper swarms caused devastation to crops throughout the 1800’s before going extinct (Lockwood 1993). In the late 1800s grasshopper-catching machines were developed. These horse-powered machines could catch and bag over 350 kg of grasshoppers that was then stored to be used for winter chicken feed. By the early 1900’s sodium arsenic dust was the principal agent used in grasshopper control. More potent pesticides such as sodium fluosilicate and chlorinated hydrocarbons were developed and put into use by the 1940’s. The problems associated with bioaccumulation of DDT in predatory birds led to the use of organophosphate compounds (malathion) that are still used today (Branson et al. 2006). Currently the USDA-APHIS Grasshopper Program conducts population surveys in the 17 Western states (Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming).
Significance of Biology

The fact that grasshoppers can be found on every continent (except Antarctica) and in every grassland ecosystem points to good evidence of the coevolution of grasshoppers and grasslands. The function of grasshoppers in grasslands has only recently been studied. Ecological networks (interconnecting restored habitat) in Africa were accessed for habitat quality by using grasshoppers as bioindicators (Bazelet and Samways 2011). The predominant life cycle and phenology of grasshoppers can be used to predict population dynamics. A cold, wet spring during the period when grasshoppers are hatching can have a negative affect on survival of nymphs. Other stochastic events such as a hot, dry spring can have the opposite outcome on population. Population modeling has found this to be generally true in northern rangelands. Ecological conditions in southern rangelands favor a cool, wet spring for population outbreaks (Joern and Gaines 1990). This has led some researchers to conclude that population outbreaks can be predicted (Lockwood 2008).

Grassland ecosystem and grasshoppers

Grasslands once covered 1.1 million km$^2$ in the United States and have largely been converted for human use. Agriculture, human settlement and grazing land have taken over the wild grasslands, leaving only 1% of the original area, or just a few hundred km$^2$ (Lockwood 1999). Early conservationists adhered to the wise use philosophy and grasslands were considered more important to develop than preserve. Today, The Nature Conservancy holds more grassland in trust (Flint Hills, Konza Prairie, etc.) than is held in government preserves. It was not until 1996
that the first government preserve was created, the Tallgrass Prairie Preserve in Kansas (Stoll and Sherow 2007). How do grasshoppers contribute to the grassland ecosystem? The few studies that exist point to a positive relationship. A study conducted at the Pawnee Grasslands showed that grasshoppers are important nutrient cyclers. They are directly responsible for the removal of carbon from plants by consumption and producing litter (grasshoppers do not consume all vegetation during foraging). Egg death also contributed to carbon in the soil layer (Rodell 1977). Another study at the National Bison Range Wildlife Refuge in Montana showed that grasshoppers enhance plant production. Grasshoppers increase nutrient cycling by increasing the proportion of litter provided by faster decomposing plants. This results in a greater availability of nutrients that in turn, increases the abundance of faster decomposing plants (Belovsky 2000). A more recent study compared fast cycling of nutrients (excrement and dead grasshoppers) to slow cycling (plant litter). They measured soil nitrogen availability and found that the litter produced by the grasshopper increased nitrogen. Depending on the decomposition rate of the plant, this could increase primary productivity of the plants. The researchers concluded that under certain conditions, grasshoppers increase plant production and should not be controlled (Belovsky and Slade 2002).

**Food web in grasslands**

Grasshoppers are an important herbivore in a grassland ecosystem. They are also an important food source for other fauna in grassland ecosystems. Grasshoppers serve as food for mammals such as coyotes and grasshopper mice (Rodell 1977). They are also a major component in the diet of grassland birds, and studies have shown that there is a direct decrease in birds when
Grasshoppers are less abundant (Bock et al. 1992). Invertebrates also predate on grasshoppers, one major predator is the *Pisaurina mira* spider (Belovsky and Slade 1993).

**Trophic cascade impacts**

There are two approaches to trophic cascades within a food chain structure. The top-down control shows that the food chain is limited by the consumers at the top trophic level. The bottom-up control shows that the system is limited by nutrient inputs to the lowest trophic level. Constructing a trophic cascade with grasshoppers as the top of the trophic level in a top-down system, how would it look? It could be similar to the one below showing the detrital food web.

![Image of a food web diagram](image.png)

*Fig. 2. Aboveground communities are affected by both direct and indirect consequences of soil food web organisms. (Right) Feeding activities in the detritus food web (slender white arrows) stimulate nutrient turnover (thick red arrow), plant nutrient acquisition (a), and plant performance and thereby indirectly influence aboveground herbivores (red broken arrow) (b1). (Left) Soil biota exert direct effects on plants by feeding on roots and forming antagonistic or mutualistic relationships with their host plants. Such direct interactions with plants influence not just the performance of the host plants themselves, but also that of the herbivores (b2) and potentially their predators. Further, the soil food web can control the successional development of plant communities both directly (c3) and indirectly (c4), and these plant community changes can in turn influence soil biota.*

Wardle et al. 2004
What happens when you remove the grasshopper from the food chain? Grasshoppers do not consume all of the plant matter that they chew. This leaves a higher concentration of plant material on the ground to be consumed by detritivores. The detrital food web can liberate the nutrients from the plant litter, which increases nutrient availability to the plants. This increases the overall productivity of plants (Wardle et al. 2004). How does the application of pesticides affect the food chain? Carbamate and organophosphate pesticides have been shown to cause mortality to earthworms and other soil microfauna (mites, etc.). The lack of soil fauna will slow the rate of decomposition of dead plant material. Nutrient cycling to plants will be also be slower (Pimentel and Edwards 1982). The pesticide diflubenzuron blocks the formation of chitin, the cellular material of mycorrhizal fungi (grows in plants roots and provides nutrients). Studies have shown that it can have detrimental effects on the health of plants by inhibiting the growth of this important symbiotic fungi (Ramos et al. 2012). In a grassland ecosystem energy flows from producers through the lower trophic levels to the higher levels in the food chain. If pesticides can kill both the organisms in the top and bottom of our trophic cascade, how does that impact the plants in the middle?
The trophic cascade above shows how the indirect pathway to plants is altered by the removal of grasshoppers and soil fauna. Application of pesticides can slow the return of nutrients to plants. If this is the case, then using pesticides can impair the growth and productivity of the very plants it is intended to protect.
Argument for Keystone Species

Grasshoppers have many predators and are an integral part of the grasslands; they can have as many as 20,000 direct and more than a billion indirect relationships within the ecosystem (Lockwood and Lockwood 2008). An argument can be made that grasshoppers were and are “a keystone species that affected the ecosystem processes on a scale equivalent to that of the bison. The normal cycling of energy, carbon and nitrogen was lost with *M. spretus* and may have not yet been restored” (Lockwood 2004). Other significant grasshopper research has recognized grasshoppers as keystone species (Sergeev 1998). Communities of grasshoppers may be essential to ecosystem functioning over long periods of time, and others show huge population variability, often becoming local and temporary keystone species.

Grasshopper Control Practices

Traditional Control-Pesticides

Since the advent of pesticides little has changed in grasshopper control methods (Branson et al. 2006). Despite calls by expert entomologists to be more proactive, pest management is just as reactive now as it was a quarter of a century ago (Lockwood and Lockwood 2008). The most commonly used pesticides for grasshopper control are carbaryl and malathion. In recent years diflubenzuron and *Nosema locustae* have been recommended. They are more target specific but slower acting than carbaryl and malathion. Diflubenzuron blocks the formation of chitin, the major component of a grasshoppers (and many other invertebrates) exoskeleton. It can take up to
several weeks to be effective and must be sprayed before grasshoppers reach the adult stage. *Nosema locustae* is a protozoan that infects grasshoppers, causing them to become lethargic and reduce their food consumption. It must be applied in bait form that the grasshoppers consume to be effective. It may take several weeks to cause mortality and may require a second application if conditions are less than ideal. The advantage of *Nosema locustae* is that is target specific to grasshoppers, however it will infect non-pest grasshopper species as well (USDA-APHIS 2002). The USDA led a 7-year study to promote lower pesticide use and greater reliance on computer model for predicting outbreaks. These tools are available to landowners and managers on the USDA-APHIS website or by mail (Stelljes and Senft 1996). An intensive literature search failed to identify data on what percentages of landowners are using these guidelines. The USDA-APHIS program provides federally supported spraying to 17 Western states. The USDA program pays 1/3 the cost and the balance is paid by the landowner. The criterion to spray is 8 adult grasshoppers per yd² (USDA-APHIS).

J.A. Lockwood has led extensive studies on the effectiveness of the Reduced Agent-Area Treatment method. As an alternative to spraying the entire outbreak area with pesticides, the area treated is reduced. The amount of pesticide sprayed is also reduced. During field trials swatches of 30 meters were sprayed in alternate patches. The most commonly used pesticides malathion and carbaryl were used. When both were applied at half the standard rate to half the area, the result was up to 90% mortality within 7 days. The RAAT method also represents an economic benefit both in direct and indirect costs of 50% (Lockwood and Schell 1997).
Biological Control

The complicated ecosystem relationship of grasshoppers and grasslands also gives great cause for concern over using biological agents to control grasshoppers. Proposals have been made by the USDA-APHIS to introduce exotic wasps, parasites and protozoans. J.A. Lockwood has raised a number of environmental and ethical concerns regarding the use of non-native biological control agents through his research and literature. The problems with biological control include unintended consequences (to other species) and once introduced there is no way of stopping it (Lockwood 1993). Currently (as of 2011) the only biological control agent registered by the EPA for use against grasshoppers is the protozoan *Nosema locustae* ([www.epa.gov](http://www.epa.gov)). Others are being currently studied by the USDA-APHIS for use. Biological control continues to be researched but is not without substantial environmental and ethical concerns.

Alternative Control Methods

Cultural Control-Prescribed Fire and Controlled Grazing

Sampling of grasshoppers after a disturbance (fire, land use changes) showed a correlation between high quality habitat and grasshopper diversity (Bazelet and Samways 2011). The direct ecosystem benefit of grasshoppers has been little studied. Grasslands evolved in relationship with herbivory by ungulates (large herbivorous mammals) and grasshoppers (Samson et al. 2004). Studies have suggested that overgrazing may contribute to outbreaks in grasshopper populations. In contrast twice over grazing methods resulted in lower grasshopper populations and no outbreaks during a five-year period (Branson et al. 2006). The twice-over grazing method
is much discussed but rarely explained. A brief overview of the process is this: two cycles of sequential movement of a grazing herd of livestock is moved through a series of three to six pastures within a 4.5 month grazing season. The first grazing cycle is between June 1\(^{st}\) and July 15\(^{th}\). This cycle will result in a more equally distributed defoliation over all the plant species present than would occur when the herd has continuous access. The second grazing cycle occurs between July 16\(^{th}\) and October 15\(^{th}\). The second pasture set is grazed in the same sequence but for twice as many days as it was during the first cycle. The exit pasture will be the entrance pasture at the start of the next season. This will result in a significant difference in soil temperature, grasshopper basking efficiency and egg development rates because less soil is exposed to direct sunlight than with season-long grazing. Under this system, conditions in both pastures are kept at sub-optimal for breeding and nymphal survival (Onsager and Olfert 2000).

The use of prescribed fire has also been studied with mixed results. Differences existed on the type of vegetation (tall-grass, mixed-grass, etc.) and the seasonal timing of the fire. The best response was in fall prescribed burns in mixed-grass prairie. In a spring prescribed fire in California’s perennial grassland, grasshopper density was reduced for two years and an increase in grasshopper species diversity was found (Branson et al. 2006). There are potential advantages to the health of our grasslands to using these alternative management practices over the use of pesticides.

**Novel and throwback GH controls**

As previously discussed, before the advent of chemical control for grasshoppers the most common practice was mechanical control. A recent paper by Cerritos et al. (2012) compared the
cost of pesticides versus mechanical control. During a five-year period in Africa, economic losses from grasshoppers totaled over $2.5 billion. Over $400 million was spent on pesticides and biological control agents, with little success. Had mechanical control been used, 10 million tons of grasshoppers plausibly could have been collected at a cost of $10 million. This is significant due to the fact that in some African countries (and in many other countries) insects are considered a viable food source. Compare this to the Western United States, where grasshoppers typically ingest 25% crop foliage at a cost of $1 billion per year (1987 dollars). During a two-year outbreak period, malathion was sprayed at a cost of $75 million (1995 dollars). The projected cost for mechanical control would have been $5 million to collect between 1 and 5 million tons of grasshoppers. Although the practice of entomophagy (insect consumption) is not common in the United States, grasshoppers could provide an excellent winter feed for poultry (Cerritos et al. 2012). Before the advent of pesticides, mechanical control was the only available method of control. The Hopper Whopper was built by Vern Erickson using 6 old car tires to be a modern day equivalent of the horse-powered machines of the 1800’s. The disadvantage of the Hopper Whopper is that it crushes the grasshoppers instead of collecting them for later use.

A two-year study in Mexico compared grasshopper populations and plots treated with pesticides against plots with mechanical control, and found R-value difference of only 0.14 between the 2 plots. In this case the mechanical control is actually manual collection of grasshoppers by local residents. In developing countries, this also can provide a significant supplemental income (up to $3000 USD per year) for rural-based families when they sell the collected grasshoppers. Grasshoppers have almost as much protein per ounce as beef. By working cooperatively, farmers and insect hunters can both benefit (Cerritos et al. 2008).
New and novel approaches to grasshopper management deserves more study. One of the most promising areas is in biopesticides, according to David Grzywacz from the National Resources Institute, the industry has seen 2% growth per annum, while the synthetic chemical market has shown a steady 1% to 2% decline per annum. One problem in this industry is the definition of a biopesticides, many authorities and regulators feel this term should only include pheromones and plant extracts. This categorization would exclude organisms such as predatory insects, viruses, bacteria, microfungi and nematodes (for example Nosema locustae used for grasshopper control). In many cases biopesticides are not seen as incompatible with organic farming. In Africa, China, and India the biopesticide Green Muscle ® (not approved for use in the USA) targets only locus and grasshoppers, and is non-toxic to farmers (Hunter 2009). This can provide both a health and economic benefit to farmers in developing countries.

One approach that has not been studied from the aspect of biocontrol is the predatory spider Pisaurina mira. These native spiders overwinter as juveniles and mature in late spring, making their lifestage correspond ideally with spring hatching grasshoppers (Schmitz 1993). Laboratory bred spiders could be released into rangelands and croplands as part of an IPM strategy. The chart below shows that these spiders are capable of consuming a biomass equal to their own.
There are also plants that have been shown to provide a natural pesticide barrier. In India a recent study on *Pongamia pinnata* L. was conducted for effectiveness at various levels of concentration. At 200 g/L of water *Pongamia pinnata* provided total control against not only grasshoppers but also damaging caterpillars and leaf suckers. The researchers coined the herbal pesticide P.H.P., and claim that is not only more effective than DDT it is much more cost effective (Tripathi et al. 2012). This plant can provide an excellent solution to the pest problem in India. While P.H.P. would not be considered a native solution in the US, it is certainly worthy of further study to determine its effectiveness. While none of these biopesticides may be the “magic bullet” that chemical pesticides (hypothetically) provide, they can be used in combination with other IPM strategies to provide a long-term solution (Hunter 2009).
Economic Cost of damage and pesticides

In the Western US severe grasshopper outbreaks can cause extensive damage to rangeland and cultivated crops. On average over 2 million acres are treated annually in the United States, at a cost of more than $5 million. The economic threshold or economic injury level is the level of pest population at which the damage becomes equal to the cost of control. The true economic threshold will vary depending on the amount and value of forage saved versus the cost of saving that forage from grasshopper herbivory. The factors to be considered are the amount of productivity on the rangeland, livestock prices, the cost of alternative sources of forage, and the cost of grasshopper control treatments (Davis et al. 1992). These factors can change from year to year depending on market and climate. In 2012, most of the Western states experienced a drought that caused the cost of hay to rise to over $200 a ton (USDA 2013). Grasshopper density increase will result in forage lost for each unit of increase per square yard. There are many variables in the effectiveness of pesticides, including the cost and the timing of application. When considering the economics of pesticides, one must also include the externalities (or indirect costs). For each hectare sprayed with pesticides, the externalities can be as high as $1.75 (2001 dollars). In the Philippines, one study found that the negative effects on humans from pesticides sprayed on rice crops can be roughly equal to the benefit of reduced crop loss. In this case the cost/benefit ratio makes the use of pesticides to not be of economic value (Weiner 2005).
It is a common fallacy to compare costs of control based solely on the cost of the pesticide used. The true cost/ha of a control program is the total budget of the program, which includes the staff, administration, survey, and application method; divided by the number of hectares treated (Hunter 2010). To be truly inclusive of all costs to this we must add the externalities of animal and human health risks and mortality. The current prescribed intervention level of grasshoppers is $8$ $GH/YD^2$, without regard to species composition, range productivity or condition. In a study conducted by Davis et al. (1992) rangeland productivity and precipitation levels were shown to be important determinants of the financial justification for treatment of grasshoppers. On productive rangeland under normal precipitation levels the economic threshold was shown to be $23$ $GH/YD^2$ when using malathion. When using either carbaryl bait or *Nosema locustae*, the threshold increases to densities of $32$ to $40$ $GH/YD^2$. With so many factors to consider, that can vary from year to year, grasshoppers cannot be managed with the simple decision such as a static economic injury level (Berry 1995).

**Decision Support Systems**

Recognizing the complexity of this situation the USDA-APHIS initiated a five-year, $15$ million Grasshopper Integrated Pest Management Program (GHIPM) in 1986. The project received a three-year extension to facilitate IPM technology implementation. The GHIPM project spawned the development of the decision-support system, named Hopper, provide information to private and public land managers regarding the economic threshold for control treatments. There are 3 components to Hopper:
1. RangeMod, simulates range forage production. When given soil and range type the program considers climatic variables to stimulate the amount of forage available for grazing.

2. HopMod, is the grasshopper population dynamics model. Based on the observed response of grasshoppers and rangeland in laboratory environments it determines the effects of grasshoppers on range forage availability. The variables considered are amount of forage eaten or destroyed by different grasshoppers species at each lifestage, grasshopper mortality, and temperature.

3. RanchMod is an economic decision model for a typical ranch. Livestock species, livestock management system, forage use, ranch size, and technology applied serve as the characteristics of a typical ranch.

While each model can be used alone, Hopper is designed to use all 3 models together. HopMod evaluates the efficiency of the 5 approved treatments and includes grasshopper species and timing of application. When RangeMod and HopMod interact they can determine what treatment is appropriate for the conditions and the amount of forage available with and without each treatment. All 3 components used together can help determine the benefit to cost ratio. When the B/C ratio is < 1 marginal benefits are determined to be less than the marginal costs. However the marginal benefits exceed the marginal costs if the B/C is >1.

RanchMod can also compare the ranchers’ additional options, such as leasing additional forage land or purchasing additional hay stocks (Skold et al. 1995). These options may net a smaller return they still may be less costly than implementation of a grasshopper control program. The graph below shows the B/C ratio for these options and also supports the findings of Davis et al. (1992), that in most cases the economic threshold is far above the recommended 8 GH/YD².


**Fig. 2.** Effect of non-treatment management adjustments on the EIL for a northern plains ranch for base, land leasing, and maintaining hay stocks cases.

Skold et al. 1995

**HOPPER** can be downloaded for free at:

http://www.sidney.ars.usda.gov/grasshopper/Support/Hopper.htm

Another DSS developed by Professor J.A. Lockwood and Professor John Hastings named Case-based range management advisor or **CARMA**, can be downloaded for free at:

http://carma.johnhastings.org/index.html
Environmental Impacts of Pesticides

Non-target impacts

Pesticides used for grasshopper control are considered broad spectrum. These pesticides kill not only pest and beneficial grasshoppers, they also kill or injure many other species (Batary et al. 2012). Of great concern is the decline of our native bees, and the economic impact of losing these important pollinators. One recent study found that crops sprayed with carbaryl and malathion had a significant decline in wild honey bee abundance and species diversity (Tuell and Issacs 2010). Evidence has been found that carbaryl and malathion are highly toxic to bees and diflubenzuron was mildly toxic (De la Rua et al. 2009). The total economic losses related to the loss of honeybees has been estimated to be over $286 million/year (Pimentel 2009).

Wildlife biologists in the USA have been concerned with the declining grassland bird populations. While no single cause has been identified, large-scale deterioration of western rangeland has been documented to be one causative factor. The causes of this degradation are breaking the fire cycle, invasion of exotic grasses, road building and especially overgrazing. Over 150 million ha of public rangelands in the west have been documented to be overgrazed (Brennan and Kuvlesky 2005). Habitat degradation and fragmentation have been identified as factors in grassland bird decline and grasshopper control programs also affect bird populations. The effect was not found to be directly related to the pesticides. Grassland birds that are primarily insectivorous declined between 10 and 21 days following pesticide application in grasslands. The reason was an indirect effect from lack of available food resources, especially for nesting chicks that need a high quality diet for maximum growth (George et al. 1995). Birds can also have an inverse effect on grasshopper populations. During a four-year study in which birds
were excluded from a plot, grasshopper densities were up to 2.2 times higher than in the control plot (Bock et al. 1992). This shows that including birds in IPM strategies will benefit both grassland birds and rangeland managers.

Other deleterious effects of using pesticides is damage to water sources. Organophosphate pesticides have been found in rivers in concentrations ranging from 6.5 mg/L to 25 mg/L. These concentrations are high enough to have adverse developmental effects on fish. In concentrations as low as 2.5mg/L, 36% of developing fish larvae showed abnormalities; and at 5mg/L there was a 28% mortality rate and 65% abnormality rate. Immune system response in fish and many other vertebrates has been shown to be impaired in concentrations as low as 0.2mg/L (Galloway and Handy 2002).

**Human impacts**

When our hunter gatherer ancestors developed agriculture more than 10,000 years ago they began a battle to protect their crops from pests. In the industrialized era farmers turned to toxic elements, such as sulfur arsenic and mercury, to fight these pests with little knowledge of how these would affect humans or the environment. The field of organic chemistry made great strides after World War II and led to the development of organochlorine insecticides such as DDT. Racial Carson’s breakthrough book, *Silent Spring*, brought to light the severe effects of organochlorines on humans and the environment. This class of pesticides can persist in the environment and lead to bioaccumulation in top predators, such as bald eagles and humans. When DDT was banned in the US (it is still used in many other countries) new pesticides were developed including organophosphates and carbamates. It was originally believed that these
classes of pesticides would not accumulate in the environment however they are even more toxic to humans than organochlorines (Hunter 2009).

The two most commonly used pesticides for grasshopper control are malathion and carbaryl both of which are in the classes of organophosphates and carbamate respectively. Even though these pesticides do not accumulate in humans like the organochlorine class they are not without hazards to human health. The way that organophosphate pesticides function is that they inhibit the enzyme acetylcholinesterase, which breaks down (metabolizes) the neurotransmitter acetylcholine. This neurotransmitter delivers information between nerve cells and muscles, allowing the muscle to contract. When the enzyme is inhibited, acetylcholine builds up in the muscles. The result can be prolonged contraction and finally, respiratory paralysis. In grasshoppers, death usually follows within hours. The EPA states that the human health effects from organophosphates can be nausea, headaches, and even death. To understand how it can cause death we can compare this to a snake bite. The venom of some snakes (for example black mamba) contains a neurotoxin. This neurotoxin also inhibits the enzyme acetylcholinesterase, the neurotransmitter acetylcholine builds up and blocks the synapses between nerve cells and muscle cells resulting in respiratory paralysis. While smaller doses of organophosphate pesticides will not result in death they have been linked to other neurological disorders, such as ADHD (Bouchard et al. 2010, Kuehn 2010), Alzheimer’s (Hayden et al. 2010), and Parkinson’s (Firestone et al. 2005, Lockwood 2000). Other studies have shown that there was a correlation between both reduced sperm production and DNA damage in human sperm as measured by elevated levels of insecticide metabolites present in urine (Meeker et al. 2004, Perry 2008). Researchers have also found strong evidence that when AChE is inhibited, it may reduce production of natural killer cells and T-cells, critical components of the human immune system.
(Bavari et al. 1991). Cases of organophosphate induced delayed poly-neuropathy (OPIDP) have been shown to produce irreversible neurological damage (Pimentel 2009).

Although organophosphate pesticides (OP’s) are quickly metabolized by the body and do not accumulate in fatty tissues the way organochlorine pesticides (DDT for example) do, they have been shown to accumulate in soil, water, air and in our food supply. Despite the common belief that the half-life of OP’s ranges from days to weeks, when researchers measured the residue in food after processing (cooking, canning, dehydrating, etc.) the results varied greatly. Dried foods showed elevated concentrations, while only foods that were peeled showed lower concentrations after processing. For foods that were not cooked or peeled, washing with water only lowered the OP concentration by 50% on average (Bajwa and Sandhu 2011). If we need further proof that OP’s are a steady component of our food supply, we can measure the metabolites of these chemicals in human urine. The metabolites of organophosphate pesticides were measured in a representative population of more than 2000 individuals aged 6-69. The metabolite of carbaryl was found in 95% of subjects and 52% had the metabolite of malathion (Barr et al. 2005). Evidence is starting to accumulate documenting that OP’s may pose a significant risk to human health.
Conservation of grasshoppers

Endangered

When you picture an endangered species, most likely a grasshopper is not what comes to mind. Yet these seemingly indestructible creatures are being added to the IUCN red list with increasing frequency. Long before the creation of the IUCN red list one of the most abundant and widely distributed grasshopper species in North America, *Melanophus spretus* or Rocky Mountain Locust, suffered a rapid extinction in the early 1900s. The widely accepted hypothesis of J.A. Lockwood, is that during a natural population decline in the late 1800s, new agricultural practices destroyed the permanent breeding grounds of the Rocky Mountain Locust (Samways and Lockwood 1998). In the Czech Republic, a long-term survey determined that over half a dozen grasshopper species should be declared regionally extinct. Across Germany it has been well documented that most Orthoptera species are in decline (Holusa 2012). An endemic and protected grasshopper *Prionotropis hystrix rhodanica*, in the south of France faces extinction due to habitat loss. The Coussou habitat of this grasshopper has been reduced from 60,000 ha to only 10,000 ha remaining today. The remaining Coussou is highly fragmented and/or altered into more than 30 patches. *Prionotropis hystrix rhodanica* only remains in the largest four unaltered fragments (Foucart and Lecoq 1998). More than 20 grasshopper species are listed as endangered or critically endangered in North America (IUCN 2013). Despite the dramatic increase in threatened or endangered grasshopper species during the last several decades, the IUCN red list does not tell the whole story. However, the Endangered Species Act fails to protect invertebrates on a taxonomic level and prohibits inclusion of a “pest” species (Czech et al. 2001). Survey
information shows a definite bias towards North America and European countries, with developing countries and islands being underrepresented (Samways and Lockwood 1998). We can only assume the taxon Orthoptera is in trouble worldwide. Considering that Orthoptera can be considered bioindicators of ecosystem health, we must listen to their raspy call:

Nineteen Hundred and Nineteen

Many ingenious lovely things are gone  
That seemed sheer miracle to the multitude,  
protected from the circle of the moon  
That pitches common things about.  There stood  
Amid the ornamental bronze and stone  
An ancient image made of olive wood —  
And gone are phidias' famous ivories  
And all the golden grasshoppers and bees.

William Butler Yeats

Translocations and re-introductions

In the field of applied species conservation, a species that is threatened with extinction due to habitat loss may be translocated or relocated by conservation managers to a new suitable location. In Germany the red-winged grasshopper (*Oedipoda germanica*) is threatened with extinction. A group of researchers collected and reintroduced a small population of *O. germanica* into the Leutratatal Nature Reserve, an area formerly inhabited by this species. Three years after the reintroduction, no *O. germanica* were found at the introduced site. One possible explanation by the researchers was higher predation pressure in the release habitat (Wagner et al. 2005).

The Mehoenui giant weta (*Deinacrida sp.*) is native to New Zealand and is threatened with extinction. In this case the researchers compared captive-breeding to wild caught populations for
re-introductions. The captive-bred population had a higher survival rate, at a lower overall program cost. The stress caused to the grasshoppers during collection and transport may have contributed to their lack of survival at the translocation site. Three different sites were selected for the translocation, none of which were an exact match for their known range and ecological habitat. As part of the experimental process some of the translocated weta were released into a protected (from predation) enclosure. The progeny from these enclosed weta will be released into the larger habitat. Despite all these precautions, a self-sustaining population has not been established (Sherley 1998). These examples show that grasshoppers can easily go extinct and re-establishment of small populations are rarely successful.

**Land managers and Grasshoppers**

**Information vs. education**

There are many sources for information but how well do they educate land managers? The survey conducted found that local sources of information (County Weed and Pest District, University, and neighbors) were favored over national sources of information (USDA, media, and internet).

**Sources of Government information**

“APHIS conducts surveys for grasshopper populations on rangeland in the western United States, provides technical assistance on grasshopper management to landowners and managers, delivers public outreach and education programs, and may cooperatively suppress grasshopper populations when direct intervention is necessary. APHIS treats grasshoppers only upon request and after determining that treatment is warranted. In some cases, APHIS rangeland treatments protect not only the rangeland, but also reduce the likelihood that the grasshoppers will move into crops and other lands that border rangeland.”


The handbook includes many of the topics covered in this paper, including chemical control, biological control, DSS, and rangeland management (includes grazing management). This site also includes the free download for the HOPPER program:

http://www.sidney.ars.usda.gov/grasshopper/Support/Hopper.htm


Includes links to the National Pesticide Information Retrieval System (NPIRS), The National Agricultural Pest Information System (NAPIS), and The National Plant Diagnostic Network (NPDN).

3) Several states have information available through the Entomology Department or Extension Office of their Universities, here are a few:

Colorado: [http://www.ext.colostate.edu/pubs/insect/05535.html](http://www.ext.colostate.edu/pubs/insect/05535.html)

South Dakota: http://pubstorage.sdstate.edu/AgBio_Publications/articles/exex5081.pdf

Nebraska: http://entomology.unl.edu/grasshoppers/12grasshopperguide.htm


These publications vary widely in the amount and quality of information provided. Some only mention chemical control (with or without the RAAT method), others include information on controlled grazing or prescribed fire as alternatives to pesticides.

**Sources of private information**

Developed by Professor J.A. Lockwood and Professor John Hastings, the Case-based Range Management Advisor can be downloaded for free at: http://carma.unk.edu/

An extensive search failed to produce any other reliable sources of information for grasshopper management that were not associated with any federal, University, state, or county program. The majority of private sources were directed at small gardeners and recommended (and usually were selling) the *Nosema locustae* product.

While there is obviously no lack of information sources available for grasshopper management, does it mean that land managers are being properly educated? Unless a land manager requests a survey from the USDA-APHIS (or another properly trained source), they may have survey error. Additionally, unless they apply for funding aid from the USDA-APHIS program, they may not use a DSS before deciding to spray pesticides. Not all of the available
sources of information include the RAAT method, which can lower both the economic and environmental costs. There is a need to better educate land managers on the choices available for grasshopper management.

Social perception and Conservation

Biophilia

E.O. Wilson (1984) describes the phenomenon of biophilia, the emotional affiliation of humans to other organisms. He also argues that the response is not genetic, but learned through our experiences. The human response can be attraction or aversion, and is usually learned through cultural experiences. Our forefathers brought with them the images of swarming locusts consuming everything in their path. After the implementation of large scale agriculture in the New World, periodic grasshopper outbreaks (*Melanoplus spretus*) reinforced a cultural aversion to grasshoppers (Lockwood 1993). Competition for limited food resources and little understanding of the mechanisms of outbreaks sealed the fate of the grasshopper as a menace to society. This could have led to the creation of a cultural biophobia of grasshoppers (Simaika and Samways 2010). However this fear of grasshoppers may serve our interests as a culture. We are not powerless against swarming locusts as our ancestors were. We have many tools to manage grasshopper populations, and many that do not cause harm to other organisms or the ecosystem. E.O. Wilson believed that to the degree we come to understand other organisms, we will place greater value on them.
Conservation and Social Perception

While humans activities can cause the extinction of a species, humans also have the capacity to attempt to save a species from extinction. Whether we choose to do so or not may depend overly on how that species is viewed by the general public. Wildlife conservation biologists have recently become aware of the importance of charismatic traits in fauna and the public support of conservation of that fauna. Humans find large size, juvenile features, and similarity to human shape most appealing (Simaika and Samways 2010). Conservation efforts tend to be focused on saving the charismatic megafauna, such as the Panda Bear (Stokes 2007). Invertebrates in general seem to hold lower esteem in the public view than other animals. Kellert (2003) conducted a survey regarding the perception and conservation attitude toward invertebrates. The largest majority expressed feelings of aversion, dislike, or fear towards most invertebrates (including grasshoppers). Of the subset of respondents that were farmers this same attitude prevailed. Only the subset of scientists and conservation organization members expressed more favorable attitudes towards invertebrates. This same trend held true when respondents were asked about economic expenditures for invertebrate conservation. When an animal is not perceived to hold economic value, potentially the way to assign it is via “willingness to pay” (Martin-Lopez et al. 2007). How much is the general public willing to pay to protect a bear compared to an insect? Further how does public preference in conservation correspond to actual dollars spend on each category (flora and fauna)? This was part of the question Czech et al. (2001) sought to answer. The results showed a public preference for mammals, birds, reptiles (mostly turtles), and fish; and not surprisingly the highest allocation of conservation funds were being spent on those same groups.
Public perception in conservation shows an obvious bias against insects and funds allocated towards conservation follows suit. It follows suit that given their lack of physically appealing traits coupled with the phenomena of biophilia, the conservation of grasshoppers is of little public concern.

Czech et al. 2001

Figure 2. Comparison of public valuation of species types to average federal and state expenditure for a species of each type. Public valuation data were proportionally transformed to allow comparison.
Methods

In order to understand the social perception of grasshoppers and how it relates to land managers control practices a survey was designed (see Appendix 1). The questions were selected to not reveal any bias for or against grasshoppers. As part of the survey, one goal was to determine if being personally impacted by grasshoppers changed the responses to the social perception of grasshoppers question. While Colorado has not been significantly impacted by grasshoppers in many years (Pat McPerrin, Denver, CO office of USDA-APHIS, personal communication, April 20, 2012), Wyoming has been severely impacted by grasshopper outbreaks for the past several years, and this was the justification for choosing it as the survey site. The selected area for the survey is Fremont County, Wyoming. In 2010 and 2011, Fremont County was severely impacted by grasshoppers. Fremont County is bordered in the north by the Shoshone National Forest and in the west by the Teton National Forest. These areas are usually not sprayed.

Fremont County’s demographics make it an optimal location for this research. The population is 40,000 and over half of the residents live on rural property. The average ranch/farm size is 2500 acres, and 75% of farm income comes from livestock. The average number of cattle per 100 acres is 4 (www.city-data.com). Together this means that there are many ranchers in the area that have been impacted by grasshoppers. There are also residents that are not farmers or ranchers and have a variety of social perceptions of grasshoppers. The Fremont County Fair, in Riverton, WY, should provide a cross section of both rural and urban residents. Subjects were
approached at the fair and requested to complete the one page survey. Survey results were obtained on August 3rd and 4th, 2012.

**Results**

A total of 41 surveys were collected, with 21 self-identified as land owners/managers and 20 self-identified as non-land owners/managers. Responses were hand-coded and converted to percentages where appropriate. For a table of the most significant results see Appendix 2.

The possible responses to the social perception question were as follows:

A) They are all pests and we should kill them all (the negative response).

B) They are not a problem unless in large numbers (outbreak), (the neutral response).

C) They are beneficial to grasslands/rangelands and should only be controlled if in large numbers (the positive response).

D) They are a natural part of grasslands/rangelands and should not be controlled (the strong positive response).
The chart above shows the answers to the social perception question for each group. No respondents answered “D” in either group. Land owners responded “A” 38% of the time, “B” 57% of the time, and “C” 5% of the time. Non-owners responded “A” 35% of the time, “B” 45% of the time, and “C” 15% of the time. The difference in responses between land-owners and non-owners were not significant. The total of the two groups together were “A” 37%, “B” 51%, and “C” 10%. When the results were expanded to determine if being personally impacted by grasshoppers changed the frequency of response “A”, the relationship showed a trend.
The frequency of “A” declined when the land-owner did not use pesticide and when they were not impacted by grasshoppers. Conversely the frequency of the “B” response increased when the land owner did not use pesticide and when they were not impacted. Of the land-owners who used pesticides, less than 5% used the Reduced Area and Agent Treatment (RAAT) method. Most of the respondents (43%) did not respond to the RAAT question, possibly indicating that they were not familiar with this method. Only 2 of the respondents (10%) received state or federal funding aid for their pesticide treatment. This constituted 25% of the land-managers that reported using pesticides for their grasshopper control.

Only 13 of the 21 land managers responded to the “where do you get your information” question, and only 9 of those reported a ranking scale in their response. For this reason, results
will be reported only on the most commonly selected categories and not the ranking of the categories.

The (Fremont) County Weed and Pest District was selected as the most common source of information, with 11 (out of 13) choosing this category. The University of Wyoming Extension Agent was selected by 9 of the respondents. The United States Department of Agriculture (USDA), neighbors, and media categories were selected by 8 of the respondents. The internet and University of Wyoming Specialists were selected by 6 and 5 respondents respectively. Two respondents selected “Other” but did not specify the source.

Cultural practices show the most consistent results as an alternative to pesticides, so the survey included a cultural control question.

“Have you ever used any cultural control methods (i.e. rotational grazing, tilling, early planting, crop rotation, cover crop in field margins)?”
Of the respondents that answered this question, 6 (28.5%) reported using a cultural control method. When asked to rank the success of the cultural control method, the mean of the response was 5.3 (on a scale of 1-10). The specific type of cultural control used was not asked on the survey, however two respondents wrote in “chickens”. If cultural control was used, respondents were asked how many years they had used the method. The responses were 1yr, 1yr, 2yrs, 5yrs., and 6yrs; with a mean of 3 yrs. More than half of these respondents had used the method for 2 years or less. This may account for the low ranking of the success. Cultural control methods may take 3 or more years of continuous practice before the ecosystem stabilizes.

Discussion

The results of the survey showed that the majority of respondents (51%) chose “B”, that grasshopper are not a problem unless in large numbers (outbreak). The next most common answer was “A”, that all should be killed. Only 10% chose “C”, that they are beneficial to grasslands and should only be controlled if in large numbers. From an ecosystem perspective, this is the “correct” answer. No respondents selected “D”, that grasshoppers should not be controlled. Statistically we would expect to see an even (25%) distribution for each response. The results were skewed to the neutral and negative responses. Based on these results we can infer that the general public does not hold an overly positive perception of grasshoppers. The slight trend of land managers to answer less “B” less frequently and “A” more frequently may indicate that this negative view increases when they are negatively impacted. The results were
not strongly correlated enough to state that a negative view of grasshoppers influenced the land managers decision to spray pesticides or not.

The cultural control question indicated that the majority (71.5%) of the respondents had not ever used any of the methods described. Of the respondents that had used cultural control the average rating was 5 (on a scale of 1-10). Most indicated that they had used the cultural control for less than 3 years, which is the suggested time it takes for the system to stabilize. Two respondents wrote in “chickens”. It is well known that birds can consume a large quantity of grasshoppers, but this control would only be practical on a small acreage. Many studies of grazing management have shown very positive results for long-term grasshopper population control (Branson et al. 2006), yet land managers are not adopting the practice.

The questions regarding the pesticide (s) used were not answered completely enough to draw any statistical significance from. It is notable that only one of the respondents indicated they had used the RAAT method. The majority did not actually indicate a response to the RAAT question, perhaps due to being unfamiliar with it. This result was disappointing considering that the method was developed by J.A. Lockwood while he was in the University of Wyoming Extension Office. It has been accepted by the USDA-APHIS program and made its way into the information provided by many other agencies. When it came to the information question, there was a preference for local sources over national. This could be due to a natural human preference to trust sources that are closer to them.
Framework for education

Many government agencies screen potential job applicants for KSAA’s (knowledge, skills, abilities, and attitudes) prior to employment. Several industries also use KSAA’s as a measure of the success of a training program. If we can extrapolate this to the area of grasshopper management, it is apparent we are only providing the knowledge. Without the skills, abilities and attitudes, the knowledge is without application. How can we best address the gap between knowledge and application?

I propose a workshop with the working title of “Sustainable Grasshopper Management”. The best approach may involve an active learning environment. Participants could be given a pre-assessment to determine their level of ecosystem function knowledge and to address misconceptions. Example questions could include:

Q: Pesticides such as malathion and carbaryl can kill soil fauna (earthworm and other decomposers).

A: True

Q: Grasshoppers are important for nutrient cycling in grasslands.

A: True

Q: There are no grasshoppers that are economically beneficial.

A: False, *Hesperotettix viridis*, feeds on noxious rangeland weeds that can be poisonous to livestock.
Next land managers are given a basic understanding of the ecosystem, including the place of grasshoppers within it. Some case studies on the effectiveness of grazing management could be presented. Understanding the entire ecosystem concept could help change the perception of grasshoppers from enemy to friend. After lunch participants are taught how to use DSS (HOPPER or CARMA) software. The day would end with a short presentation about the benefits and draw-backs of the most commonly used pesticides. This would include the RAAT method. Since grazing management shows the best promise for non-chemical control, the following day the workshop participants can be taken to a field model of twice-over grazing. Even with proper grazing management, grasshopper populations may occasionally reach outbreak levels. Since pesticide use may still be necessary under these conditions, a live demonstration of the RAAT method would be conducted. The curriculum would emphasize that grazing management takes long-term commitment to be effective, but is not mutually exclusive to the use of pesticides should an outbreak occur. The day would end with a post-assessment and an open Q and A session. A certificate of completion would be presented.

The only questions that remains are, how do we motivate land managers to attend? And who pays for the workshop? If the USDA-APHIS program would allocate funds towards prevention, and not just pesticide treatment, their investment could pay off. Due to the field demonstrations portion of the workshop, they would probably need to be regionally situated. Experts from local University Extension office and Weed and Pest Districts could be recruited to facilitate the workshop, providing the local source(s) preferred. It is of course unrealistic to expect that every land manager would attend such a workshop. If the results of the survey hold as standard, then people hold the opinion of their neighbors in nearly as high regard as other expert authorities. So this knowledge would spread via word-of-mouth within communities.
Conclusion

Grasslands may be the most endangered ecosystem on earth, with less than 1% of unaltered habitat remaining (Stoll and Sherow 2010). Along with this loss of habitat comes a loss in biodiversity. Honeybees and grassland birds have experienced steep declines in populations over the past few decades (Tuell and Isaacs 2010, Brennan and Kuvlesky 2005). Recently these declines have been linked to pesticides, either by direct or indirect effects. In the U.S.A. on average over 2 million acres are sprayed with pesticides to eradicate one perceived pest, the grasshopper.

Looking at the ecosystem as a macrocosm instead of the usual microcosm would move the grasshopper from a perceived pest to a beneficial part of the ecosystem. They are important nutrient cyclers, food for many of the omnivores and carnivores, and can be used as bioindicators of grassland health (Bazelet and Samways 2011). When pesticides are applied in grasslands they can have detrimental effects on soil fauna, mycorrhizal fungi, and limit nutrient cycling. The result may be impaired functioning of the very plants pesticides are intended to protect.

It would be futile to deny that grasshoppers are responsible for economic damage. On average they are responsible for $1.25 billion a year in lost forage that could be fed to livestock (Branson et al. 2006). When land managers decide to spray pesticides, are they always using the best available tools and methods? Decision Support Systems (DSS) are available for download without cost; however no statistics are available on how often they are used. The program(s) may prove intimidating to the average untrained user. The Reduced Area-Agent Treatment method was developed by J.A. Lockwood can be of both economic and ecological benefit. Making better
decisions may reduce some pesticide use, but are there other factors that influence a land managers decision?

In the public’s perceptions regarding conservation, there is a strong preference towards charismatic megafauna, with invertebrates rated low in conservation status (Kellert 2003). How does this affect a land manager when deciding to spray pesticides or not? To determine if social perception may influence land managers decisions, a survey was conducted. The respondents were equally distributed between land managers and non-land managers. To the perception question regarding grasshoppers, 37% thought all grasshoppers should be killed (A, negative response). The belief that they were not a problem unless in outbreak (B, neutral response) was chosen by 51% of respondents. Only 10% of respondents chose that grasshoppers were beneficial and should only be controlled if in large numbers (C, positive response). When these results were correlated between impact by land managers and social perception response, there was a slight trend to answer A more frequently and B less frequently (no one responded C when impacted). The results were not strongly correlated enough to determine if the land managers perception of grasshoppers influenced their grasshopper management practices.

The source of information portion of the survey showed a slight preference towards local sources over national. However there is a difference between information and education. Land managers clearly need to be educated on total ecosystem functioning and making the best economic and environmental decisions. Workshop settings have been proven to be a successful model for practical education, especially if conducted within an active learning environment. The USDA-APHIS program has allocated millions of dollars to promote lower pesticide use. They may invest in such an educational program. There is more at stake than can be explained by a simple economic argument. In the eloquent words of Aldo Leopold we must “cease being
intimidated by the argument that a right action impossible because it does not yield maximum
profits, or that a wrong action is to be condoned because it pays.’’ The Sustainable Grasshopper
Management Workshop could help land managers to develop what Leopold refers to an
“ecological conscience”. The more we understand an organism, the more likely we are to
carefully consider an action that would cause harm to it. When land managers fully understand
the functions of grasshoppers within a grassland ecosystem, they may change their perception of
grasshoppers from pest to a beneficial species.
Appendix 1

Grasshopper Management Survey

1. Do you own/lease cropland or rangeland? If no, skip to question #12. Yes____ No____

2. If yes, have you been impacted by grasshoppers? If no, skip to question #9. Yes____ No____

3. If yes, what control measures do you use? ______________________________________

4. If pesticide, when and what did you treat with? ____________________________________

5. Did you use the RAAT (Reduced Agent and Area Treatment) method? Yes____ No____

6. Did you apply for funding aid? Yes____ No____

7. On a scale of 1-10 (1 = I never get my information from this source; 10 = I always get information from this source) please rate the following sources of information about grasshopper control practices:
   ___Neighbors                          ___Weed and Pest District
   ___University Extension Agent          ___University Specialists
   ___US Department of Agriculture        ___Newspapers, radio and other media
   ___Internet sources: ______________    ___Other ______________________

8. How reliable so you considered the source to be (1 = not at all reliable; 10 = extremely reliable)
   ___Neighbors                          ___Weed and Pest District
   ___University Extension Agent          ___University Specialists
   ___US Department of Agriculture        ___Newspapers, radio and other media
   ___Internet sources: ______________    ___Other ______________________

9. Have you ever used any cultural control methods (i.e. rotational grazing, tilling, early planting, crop rotation, cover crop in field margins)? If no, skip to question #12. Yes____ No____

10. If cultural control methods were/are used, for how many years? ___________________________

11. On a scale of 1-10, describe the success of the cultural control methods. (1=not successful, 10=very successful) ______

12. Please check your personal feeling about grasshoppers:
   ____a) They are all pests and we should kill them all.
   ____b) They are not a problem unless in large numbers (outbreak).
   ____c) They are beneficial to grasslands/rangelands and should only be controlled if in large numbers.
   ____d) They are a natural part of grasslands/rangelands and should not be controlled.
## Appendix 2

<table>
<thead>
<tr>
<th>Type</th>
<th>Qty</th>
<th>Impacted</th>
<th>Pesticide</th>
<th>RAAT</th>
<th>Funding</th>
<th>Cultural</th>
<th>A</th>
<th>B</th>
<th>C</th>
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<tbody>
<tr>
<td>Landowner</td>
<td>21</td>
<td>14</td>
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<td>8</td>
<td>4.8%</td>
<td>2</td>
<td>9.5%</td>
<td>6</td>
<td>28.6%</td>
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<tr>
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<td></td>
<td>7</td>
<td>35.0%</td>
<td>9</td>
<td>45.0%</td>
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<tr>
<td>Total</td>
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<td></td>
<td></td>
<td></td>
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<td>36.6%</td>
<td>21</td>
<td>51.2%</td>
</tr>
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<table>
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<th>B</th>
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</thead>
<tbody>
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<tr>
<td>Nonowner</td>
<td>35.0%</td>
<td>45.0%</td>
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Bibliography


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