An Evaluation of the Costs Associated with Implementing Management Interventions for Control of *Brucella abortus* in Yellowstone Bison and Elk

Study Plan

by

Randal R. Rucker

and

Myles J. Watts

March 24, 2014

An Evaluation of the Costs Associated with Implementing Management Interventions for Control of *Brucella abortus* in Yellowstone Bison and Elk

Problem Statement

Brucellosis is a reproductive disease, causing abortion, stillbirths, infertility, and reproductive lesions in ungulate hosts (Cheville et al. 1998; Rhyan 2013a). The disease, bovine brucellosis, is common to bison and elk of the Greater Yellowstone Area (GYA) (Cheville et al. 1998). Cattle are susceptible to brucellosis, and there is potential for transmission between wildlife and cattle grazing within the GYA (Higgins et al. 2012). Transmission occurs primarily through ingestion of the disease agent *Brucella abortus* from aborted fetuses, birth placenta, and associated birth fluids and secretions (Cheville et al. 1998; Carvalho-Neta et al. 2010).

Historically, brucellosis was endemic in U.S. cattle; national herd prevalence was estimated to be 7% and within herd prevalence 11-12% (Wright 1937). In 1934, the United States implemented a federal- state-cooperative brucellosis program (Cheville et al. 1998). Test and slaughter and depopulation efforts by this program have since reduced brucellosis to 0.0001% of all cattle herds (USDA 2010). Today, brucellosis is considered a local problem. Cattle herds bordering the GYA in regions of Montana, Idaho, and Wyoming are at the greatest risk of contracting brucellosis from bison or elk. From 2002-2012, there were thirteen domestic livestock herds identified with brucellosis in the GYA, all of which were traced back to elk (Rhyan et al. 2013b).

The enzootic nature of brucellosis in bison and the increasing seroprevalence of brucellosis in elk (Cross et al. 2010) support the notion that the disease will only be eradicated in cattle when it is controlled in wildlife. Until then, brucellosis will continue to pose a threat to the cattle economy. Some have proposed adaptive management of brucellosis in wildlife, enabling multiple management strategies with varying levels of efficacy to be selected under different scenarios (White et al. 2013). Management strategies that show the greatest promise for reducing prevalence of brucellosis in bison include vaccination, sterilization, and test and slaughter (Ebinger et al. 2011; Treanor et al. 2010).

The proposed project will evaluate the costs of bison management strategies designed to reduce disease prevalence and risk of transmission to cattle. Disease transmission dynamics between cattle, bison, and elk will be considered. Costs of responding to a brucellosis outbreak in cattle will be included in the assessment, as will estimates of the costs of suppression strategies. Recent research suggests that a significant reduction in the proportion of brucellosis-positive bison can be achieved through intensive vaccination (Treanor et al. 2010). However, a substantial reduction of wildlife disease prevalence may not be feasible with the tools (i.e., vaccine, and vaccine delivery methods) that are currently available. For this reason we will also estimate the costs of developing a more effective vaccine against brucellosis infection in domestic livestock and wildlife.

Background

Brucellosis is a global disease, affecting both humans and animals. The disease is caused by the bacterial genus *Brucella* and has been thought to date back to Egyptian times (Pappas and Papadimitriou 2007). Many names have been used to describe brucellosis infection; Bang's disease, Malta fever, and Undulant fever. *Brucella* species are potential agents for bioterrorism. The Center for Disease Control currently lists *Brucella* bacteria as category B bioterrorism agents, a result of their infectiousness and transmissibility via aerosol means (Seleem et al. 2010).

Global Distribution of Animal Infection

Worldwide, *Brucella abortus, Brucella melitensis, Brucella suis,* and *Brucella ovis* are the primary disease causing agents of brucellosis in livestock, although in the United States the disease is limited to *B. abortus* and *B. suis* (Godfroid et al. 2013). Livestock production systems that rely on pastoralism are particularly prone to high rates of brucellosis infection (Racloz et al. 2013). In other regions such as the GYA, wildlife brucellosis is important, and is epidemiologically linked with brucellosis in livestock (Godfroid et al. 2013).

Brucella abortus is found predominately in cattle but also in wildlife reservoirs in North America (Godfroid et al. 2013) and buffalo in Africa (Alexander et al. 2012). In many developed countries bovine *Brucella abortus* has been eradicated or it exists at low levels due to continued control and surveillance (Seleem et al. 2010). *Brucella melitensis* affects small ruminants and has historically been a problem in European countries (Godfroid et al. 2013). *Brucella ovis* is common to sheep and is reportedly prevalent in major sheep producing countries (Xavier et al. 2010). *Brucella suis* is found mainly in boars, hares, reindeer, and caribou (Godfroid et al. 2013). Exposure to *B. suis* often occurs through contact with feral swine found in regions of North America and Australia, and wild boar in Europe (CDC 2009; Godfroid et al. 2013).

Global Distribution and Transmission of Human Infection

Annually an estimated 500,000 people become ill with brucellosis worldwide, with rates ranging per country from 0.09 to 1603 cases per 1 million people (Pappas et al. 2006). In regions of Mexico, South America, the Mediterranean Basin, the Balkan Peninsula, Asia, and Africa, infections by the genus *Brucella* are a major human health risk (Pappas et al. 2006). Syria in particular faces the highest rates of human infection, with the number of cases doubling in recent years (Pappas et al. 2006). Distribution of the disease has changed considerably over time. Levels of infection have fallen in France, Israel, and Latin America and have risen in Central Asia (Pappas et al. 2006). Countries currently considered free of human brucellosis infection are Australia, Canada, Cyprus, Denmark, Finland, The Netherlands, New Zealand, Norway, Sweden and the United Kingdom (Seleem et al. 2010).

Human brucellosis is considered a minimal public health threat in the United States, although it is a nationally notifiable disease (CDC 2014). Seventy nine human cases were reported in 2011 (CDC 2011), and these were likely contracted from out-of-country sources (Pappas et al. 2006). These numbers are down dramatically due to implementation of the national bovine eradication program (Pappas et al. 2006) and with advancements in milk pasteurization (Young and Corbel 1989). In 1947 a total of 6321 human cases were reported in the United States, caused mainly by *Brucella abortus* in cattle (Wise 1980). Within states encompassing the GYA, two human cases of brucellosis were reported in Idaho and no cases were reported in Wyoming and Montana for the year 2011 (CDC 2011).

Infection in humans is primarily a result of the maintenance of brucellosis in animals (Godfroid et al. 2013). Transmission of brucellosis to humans occurs through consumption of contaminated meat and milk products, inhalation of infectious aerosols, or directly through contact with infective secretions or tissues (Young and Corbel 1989). Most human cases are attributed to *Brucella melitensis,* from consumption of contaminated goat or sheep milk, while cases due to *Brucella abortus* and *Brucella suis* are generally occupationally related (Seleem et al. 2010). Individuals classified as hunters, health professionals, laboratory personnel, and abattoir workers are at a higher risk of exposure to brucellosis and thus infection (Young 1995; Young and Corbel 1989). In the United States, the leading cause of human infection is *Brucella melitensis,* often acquired through travel or from consumption of imported contaminated food (Pappas et al. 2006).

Brucellosis is a systemic disease, with symptoms appearing in humans within 2-3 weeks of infection (Young 1995). Clinical symptoms include signs of fever, weight loss, chills, drenching sweats, swelling of the liver and spleen (Al Dahouk et al. 2013), and in rare instances death (US GAO 2008). Successful treatment of brucellosis patients is possible through the appropriate selection of antibiotics, taken for the prescribed length of time (WHO 2006). Resistance of *Brucella abortus* to antibiotics does not appear to be common in human patients but has been reported in some instances (De Rautlin de la Roy et al. 1986). Widespread use of similar antibiotics in animals could increase the risk of treatment failure in humans, and thus is not recommended (WHO 2006). Patients may relapse or be characterized as chronic, if clinical symptoms persist more than 12 months (WHO 2006).

Brucellosis in the Greater Yellowstone Area

In the United States *Brucella abortus* still remains enzootic in the free-ranging elk and bison of the Greater Yellowstone Area. Through serology, the disease was first detected in 1917 in Yellowstone bison (Mohler 1917) and was believed to have originated from the introduction of cattle to the continent (Meagher and Meyer 1994). By 1930, the disease had been discovered in elk at the National Elk Refuge (Murie 1951). Today about 40-60% of the Yellowstone bison are seropositive for brucellosis (Treanor 2013). In GYA elk, seroprevalence levels have historically been greater for those with access to feedgrounds versus those that are free-ranging (Cross et al.

2010). Between 1993-2009, ongoing surveillance in Wyoming indicated annual herd seroprevalence levels ranged from 3-59% for elk attending feedgrounds, and 0-7.4% for free-ranging elk (Scurlock and Edwards 2010). More recently data have suggested seroprevalence in free-ranging elk herds has been increasing to levels similar to feedground elk within the GYA (Cross et al. 2010). An increase from 0-7% to 8-20% was reported for four free-ranging elk-herds surveyed in 1991-1992 to 2006-2007, indicating brucellosis may be capable of self-maintenance in some elk populations (Cross et al. 2010).

Brucella abortus Reservoirs

Bison, elk, and cattle are the primary hosts of *Brucella abortus* in North America. Other wild ungulates such as deer, pronghorn, moose, and bighorn sheep do not appear to be important reservoirs (McCorquodale and DiGiacomo 1985). Moose have been found naturally infected with brucellosis, where the disease was severe to fatal (Fenstermacher and Olsen 1942; Jellison et al 1953; Corner and Connell 1958). In horses, *Brucella abortus* may cause a disease known as fistulous withers (Cohen et al. 1992; Johnston 1945). Opossums, raccoon, coyotes, foxes, and wolves may also carry *Brucella abortus* but do not appear to be important in maintenance of the disease (Schnurrenberger et al. 1985; Davis et al. 1979; Tessaro 1986).

Brucella abortus Pathogenesis

Bacterial pathogenesis by bovine *Brucella abortus* has been reviewed by others and is discussed briefly below (Carvahlo Neta et al. 2010; Xavier et al. 2010). *Brucella abortus* is considered an intracellular pathogen because it can survive and replicate in phagocytic and non-phagocytic cells (Ko and Splitter 2003; Xavier et al. 2010). Invasion of the host usually occurs through the gastrointestinal tract (Payne 1959), after being ingested or inhaled (Ko and Splitter 2003). Once inside, the bacteria is spread through the lymph nodes (Ko and Splitter 2003). Virulence factors aid the bacteria in surviving long periods of time within macrophages (He 2012). Eventually the uterus, genitals, and mammary gland may become infected as a result of the dissemination of *Brucella abortus* throughout the blood (Ko and Splitter 2003; Carvahlo Neta et al. 2010). Following acute infection, bacteria may persist in lymphatic tissue, leading to a chronic condition (Xavier et al. 2010).

Brucellosis Symptoms in Animals

Brucellosis is a reproductive disease of livestock, leading to abortions, stillbirths, reproductive lesions, and infertility (Cheville et al. 1998). Abortions are most common in first calf heifers (Morgan 1969; Davis et al. 1991; Rhyan 2013a) and generally occur in the last trimester (Rhyan 2013a). Abortions are a result of inflammation of the placenta, due to the pathogens tropism for trophoblastic tissue (Payne 1959; Smith 1919). Infected dams that do not abort may produce calves that are normal, weak, or still born, and *Brucella abortus* may still be shed in live birth material (Rhyan et al. 2009).

Lesions of the male genital organs are common to cattle, bison, and elk infected with brucellosis (Rhyan et al. 1997; Lambert et al. 1963; Rankin 1965; Rhyan 2013a), although lesions in male elk may be less severe (Rhyan 2013a). Females rarely exhibit lesions of the mammary organs but inflammation due to mastitis has been reported in cattle (Payne 1959; Xavier et al. 2009). Breeding soundness exams have indicated reproductive efficiency may be lower in bulls infected with *Brucella abortus* (Frey et al. 2013).

Sources and Transmission of Brucellosis in Animals

Oral ingestion of the pathogen is the primary means for an ungulate to contract brucellosis (Meagher and Meyer 1994). Ingestion occurs from direct or indirect contact with infected animals or environmental sources of the pathogen. The most significant source of *Brucella abortus* is contaminated placenta, fetuses, and birth material (Cheville et al. 1998; Carvalho-Neta et al. 2010). Brucellosis is also known to persist in vaginal secretions (Lambert et al. 1961; Manthei and Carter 1950; Rhyan et al. 2009), milk (Rhyan 2013a; Nicoletti 1980), and in male's semen (Robison et al. 1998; Lambert et al. 1963).

Venereal transmission of *Brucella abortus* appears to be unlikely in both cattle and bison (Robison et al. 1998; Rankin 1965; Thomsen 1943), as opposed to other *Brucella* species where the disease is transmitted via this route (Enright 1990; Wanke 2004). A possible explanation for the low likelihood of venereal transmission by bulls is the low levels of infective bacteria present in the semen (Frey et al. 2013). Compared to natural service, artificial insemination has been shown to pose a risk for *Brucella abortus* transmission (Manthei et al. 1950; Cheville et al. 1998). In studies where semen was placed directly into the uterus, *Brucella abortus* was shown to be transmitted (Manthei et al. 1950; Uhrig et al. 2013). Bacterial uptake mechanisms have been proposed to aid in *Brucella abortus* surviving within the uterine epithelial compared to the vaginal epithelial (Cheville et al. 1998).

Milk is a source of *Brucella abortus* because bacteria replicate in high numbers in mammary glands (Cheville et al. 1998). Consequently, calves suckling from infected mothers are at risk of contracting brucellosis through the milk. Actual rates of transmission from mother to calf via milk are unknown. Maternal antibodies do not appear to play a significant role in protection of the calf from brucellosis (Rhyan et al. 2009).

Brucellosis Prevalence in Yellowstone Bison

Recent research suggests female bison become infected with brucellosis at a young age but recover with increasing age (Treanor et al. 2011). Tissue culture results of female bison have indicated the average age of infection is three years old (Treanor et al. 2011). Susceptibility of young females to brucellosis may be a result of their poor nutritional status (Treanor 2013). Additionally, newborn calves and juveniles are highly susceptible and become infected as a result of their association with diseased females (Treanor 2013). Although positive test reactions in calves may be a result of passive transfer of antibodies from mothers to calves during nursing,

once the calves reach five months of age these antibodies begin to wane and the calf becomes seronegative (Rhyan et al. 2009).

Population Density

Population density may play a role in brucellosis persistence in free-ranging elk (Cross et al. 2010). Higher rates of seroprevalence in elk found outside of feedgrounds have recently been attributed to the increased density of these animals on winter pastures accompanied by abortion events (Cross et al. 2010). In bison, brucellosis has been shown to be more persistent in bison herds of 200 head or more (Dobson and Meagher 1996).

Inter-Species Transmission

Much remains to be learned about the rates of disease transmission between wildlife and domestic livestock. Brucellosis cases in GYA cattle appear to be a direct result of the spatial overlap with infected GYA wildlife. Research suggests that harsh winter conditions, lack of available forage, and increasing populations cause elk and bison to migrate onto grazing lands to later be occupied by cattle (Craighead 1972; Cheville et al. 1998; Plumb et al. 2009; Geremia et al. 2011; Schumaker 2013). Hunting and predation also contribute to elk migration onto private lands (Proffitt et al. 2009). Yellowstone National Park elk and bison normally calve between April and June, with brucellosis abortion events occurring at late gestation (Cheville et al. 1998; Jones et al. 2010; Schumaker 2010).Co-occupation of habitat by cattle and wildlife during infectious births or abortions is a concern for brucellosis transmission (Jones et al. 2010; Schumaker 2013). Recently, the National Park Service has maintained spatial separation of bison and cattle to reduce the likelihood of transmission events (Schumaker 2010; Kilpatrick et al. 2009). In addition, there has not been a documented case of brucellosis in cattle from GYA bison (Kilpatrick et al. 2009). Instead, current research identifies elk as a likely source of transmission to cattle via spatial overlap (Proffit et al. 2011; Schumaker et al. 2013). These data are further supported, by recent brucellosis outbreaks in domestic livestock herds traced to elk sources (Rhyan 2013b).

Many have speculated that the high seroprevalence of brucellosis in elk is a result of transmission events with bison (Cheville et al. 1998; Schumaker 2013). A study assessing seroprevalence of elk sharing winter range with bison however reported similar seroprevalence rates to those populations not sharing winter range with bison, 3% versus 0-1%, respectively (Ferrari and Garrott 2002). Only recently have data supported self-maintenance of brucellosis in elk herds (Cross et al. 2010). Brucellosis seroprevalence was shown to increase from 0-7% in 1991-1992, to 8-20% in 2006-2007 for four out of six GYA elk units not aggregating on feedgrounds (Cross et al. 2010). In the other two elk units there was no statistically significant change in brucellosis herd seroprevalence. The low likelihood of a transmission event between bison and elk was further indicated by a risk assessment using spatial overlap data (Proffitt et al. 2010). Self-maintenance of brucellosis in free-ranging elk herds is believed to be a result of

population size and aggregation of elk during the abortion period (Proffitt et al. 2010; Cross et al. 2010).

Contact with environmental sources of *Brucella abortus* from infectious births and abortions is a transmission risk to cattle and wildlife. *Brucella abortus* has been shown to persist in the environment after parturition events, although ultraviolet light and scavengers may limit the pathogen's persistence in the environment (Cook et al. 2004; Aune et al. 2012). In one report *Brucella abortus* field strain persisted up to 43 days at natural birth and abortion sites in the GYA (Aune et al. 2012). The pathogen was also capable of surviving longer on birth material in February versus May due to differences in sunlight and temperature (Aune et al. 2012). Cook et al. (2004) reported scavengers were capable of consuming 90% of fetuses within 2.9-5.9 days in regions of Wyoming's National Elk Refuge, state feedgrounds, and Grand Teton National Park.

Diagnostic Testing

Brucellosis is detected in diseased livestock through serological testing, although these tests are not perfect. There is a risk of falsely identifying animals as brucellosis positive or brucellosis negative. Infection by brucellosis is often confirmed through tissue culture and bacterial isolation, although it is possible for the pathogen to be missed in sampled tissue. Serological tests have played an important role in directing eradication efforts by identifying brucellosis positive animals and herds. The first test to be used was the standard tube agglutination assay in cattle (Ragan 2002). The preferred test today is the fluorescence polarization assay, which is cheaper and more efficient than conventional assays (Gall and Nielsen 2004), such as the ring test. These diagnostic tests are important for surveillance and federal requirements for states to maintain disease free status (USDA 2010). For instance, domestic livestock transported out of the designated surveillance areas of the GYA are required to be tested and confirmed brucellosis free.

Goals

Goal I: Cost-Assessment of responding to a brucellosis outbreak among cattle in Montana using the APHIS interim rule

Background: A brucellosis outbreak in cattle can impose substantial costs on the affected producer and may also result in a considerable burden on taxpayers. Economic losses result from poor reproductive efficiency, reduced access to markets, and the federal requirement to control the disease through culling and quarantine. Designated surveillance zones have recently been created in the regions bordering the GYA. Within these regions there is mandatory identification and female calfhood vaccination. It is believed that the creation of these zones reduces the spread of brucellosis infection and thus economic losses (MDOL 2011). The benefit from creating these zones has been estimated at 5.5 to 11.5 million dollars per year by the Montana Department of Livestock (MDOL 2011). Calfhood vaccination of cattle with RB51may provide protection against abortions and fetal infection, but its ability to prevent brucellosis infection in cattle is

limited (Olsen 2000). In all recent domestic livestock outbreaks, animals were believed to have been vaccinated for brucellosis (Rhyan 2013b).

One of the objectives of this proposal is to assess the costs associated with a brucellosis outbreak in Montana cattle herds. Past research has indicated the economic losses of a brucellosis outbreak to a 400 head cow-calf operation may be substantial, $40,181 for depopulation beyond the government indemnity payment and $134,818 for quarantine over a one year period (Wilson 2011). Total costs incurred at the federal, state, local, and producer level for a brucellosis outbreak in livestock have not been estimated. Prior to 2010, a state's disease free status was revoked either if more than two brucellosis positive herds were detected in a two year period, or if a single brucellosis positive herd was detected and not depopulated within 60 days (USDA 2010). In 2010 these provisions were modified. Since then, when a state's disease free status is at risk, test and removal and approved management strategies have been used to contain the disease, rather than requiring whole herd depopulation. This new approach has been in effect for almost four years during which Montana has had four domestic livestock herds infected by brucellosis (USDA 2013). Thus, an important component of this cost-assessment will be to determine the total costs associated with responding to an outbreak in domestic livestock under the current regulations at the federal, state, local, and producer level. This assessment will consider all activities associated with the epidemiological investigation and herd quarantine process including trace back of reactors, surveillance of adjacent herds, investigation of sources of infection, implementation of agreed upon herd plans, test and removal, and assurance testing.

Goal II: Cost Assessment of Disease Management Interventions

Objective 1: Compare the costs associated with specific management strategies to eradicate brucellosis in Yellowstone bison and elk.

Objective 2: Compare the costs associated with various management strategies to reduce brucellosis in bison and elk.

Objective 3: Compare the costs of different spatial-temporal interventions to reduce transmission of brucellosis from bison to cattle (including via elk).

Management Interventions Background: Brucellosis control or prevention strategies in either cattle or wildlife include: 1) methods to reduce *Brucella abortus* infection within the animal, 2) biocontainment activities that target positive animals within a herd, or 3) management activities that prevent transmission between animals. The most commonly discussed management strategies are whole-herd depopulation, vaccination, test and removal, hazing, hunting, fertility control, and habitat expansion. Whole herd depopulation is the method of destroying all animals in a herd to eliminate any possible reservoirs of infection. During the Great Depression whole cattle herd depopulation was common both to remove brucellosis and to reduce cattle numbers (Ragan 2002). Until the changes in 2010, depopulation of positive cow herds was also important for a state to maintain disease free status.

Brucella abortus vaccination acts to provide acquired immunity, and to reduce abortions and fetal infection in bison (Olsen et al. 2003; Olsen et al. 1998). Test and removal is the process whereby animals are quarantined, tested for exposure to *Brucella abortus* antibodies, and then slaughtered if found to be positive. A recent study by the Montana Fish, Wildlife, and Parks verified that brucellosis can be cleared from an infected group of juvenile bison within a quarantine facility through repeated testing and removal of positive reactors (MFWP 2010). Hazing allows for the spatial and temporal separation of bison and cattle on grazing land. Bison that migrate out of the park in the winter are encouraged to retreat back to the park each spring through hazing. In the winter, bison may also be hunted by licensed hunters and American Indian treaty hunters, a recent amendment to the Interagency Bison Management Plan (White et al. 2011; NPS 2005). Sterilization, estrus suppression products, or immunocontraceptives prevent pregnancy and are not currently used in bison. Habitat expansion involves allowing bison to graze public and private lands, which may require purchase of grazing rights or easements. At present, hazing and test and removal are the primary means of controlling the brucellosis infected Yellowstone bison population. Vaccination may play a greater role in the future.

Suppression Effectiveness: There have been a number of studies that have assessed the effectiveness of various brucellosis management strategies in wildlife (Peterson et al. 1991; Dobson and Meagher 1996; Treanor et al. 2010; Ebinger et al. 2011; Hobbs et al. 2013). One result that is common to these studies is the substantial amount of time and resources required for current management strategies to reduce brucellosis infections in GYA wildlife.

In one of the earlier models, researchers assessed S19 vaccination of Grand Teton bison when: 1) females were vaccinated at calfhood, 2) females of all ages were vaccinated, and 3) seropositive bison were removed and females were vaccinated (Peterson et al. 1991). Researchers simulated model uncertainty surrounding vaccine efficacy using S19 field data from Texas A&M. Vaccine efficacy estimates ranged from 24%-90% for calfhood vaccination and 65%-81% for vaccination of females of all ages. The proportion of animals contracting brucellosis was modeled using a fixed transmission risk assumption, where interspecies transmission dynamics did not play a role. Under all three management scenarios, the reduction of brucellosis seroprevalence below 20% after 20 years was shown to be unsuccessful. To reduce seroprevalence levels below 10%, a sensitivity analysis indicated the transmission rate would need to be lowered below 5% (Peterson et al. 1991).

Dobson and Meagher (1996) developed a frequency and density-dependent brucellosis transmission model, to assess the relationship among the annual cull rate and brucellosis prevalence in Yellowstone bison. Historic data from Yellowstone bison were used and included: recruitments, removals, population size, prevalence and culling intensity. Bison-to-bison transmission rates were scaled by body weight for both density and frequency-dependent scenarios. Using these transmission values it was determined that the bison would have to be eradicated before a successful reduction in brucellosis prevalence could be achieved, unless there

was a way of identifying and removing infected animals (Dobson and Meagher 1996). This analysis did not incorporate interspecies transmission of brucellosis from elk.

Other researchers developed an individual-based simulation model, to determine the effect of boundary and remote vaccination of female Yellowstone bison on brucellosis seroprevalence (Treanor et al. 2010). This model was developed to align with guidelines of the Interagency Bison Management Plan, which suggested the implementation of a remote bison vaccination program. Captured in the model were yearly processes that controlled population demographics and vaccination status of Yellowstone bison, as well as daily processes influencing individual bison exposure to *Brucella abortus*. Transmission of brucellosis from elk to bison was accounted for and occurred at a rate of 0.01. Of interest was the resulting 66% reduction in brucellosis seroprevalence under the scenario where 29% of female bison were vaccinated remotely, or at boundary capture, with a 50% efficacious vaccine over 30 years. A less successful reduction in brucellosis seroprevalence was indicated when vaccination was limited to calves and yearling females that were captured at the boundary upon leaving the park, or were vaccinated remotely when found within the park. To prevent reversing the desired effectiveness of the vaccine, researchers concluded that a long term vaccination effort would be required to effectively mitigate brucellosis infection in Yellowstone bison (Treanor et al. 2010).

Using similar transmission dynamics as the models discussed above by Treanor et al. 2010, researchers simulated the effect of sterilization, vaccination, and test and removal on brucellosis seroprevalence of Yellowstone bison (Ebinger et al. 2011). An advancement of this model was the application of both selective and non-selective treatments to female bison. For test and removal and sterilization, selective referred to the application of treatment to young, pre-reproductive, and seropositive animals, while non-selective referred to the application of treatment to seropositive animals of any age. In the case of vaccination, selective referred to vaccinating only seronegative female calves, while non-selective referred to vaccinating all female calves at the boundary with no serological test. To simplify the model, researchers modeled efficacy of sterilization and vaccination at 100%. All brucellosis control strategies were assessed under scenarios where a target number of animals (50-100) were given the treatment annually. Selective sterilization and test and removal were found to be most effective at reducing brucellosis, but they also required additional effort to identify seropositive animals. Eradication of brucellosis was shown to be possible in less than 35 years when sterilization was implemented non-selectively to 75-100 head per year. Due to the targeting of seropositive animals, 3% to 13% of sterilization and test and slaughter simulations exhibited an initial decrease followed by a substantial increase in brucellosis seroprevalence. The authors suggested this increase may have been an effect of reduced herd immunity (Ebinger et al. 2011). Vaccination was the least successful at reducing brucellosis in bison. Although when vaccination of seronegative bison was combined with non-selective sterilization of approximately 5% of seropositive bison, it was capable of reducing brucellosis seroprevalence to 15-25%, at the 100 head target level. This model was useful in demonstrating the effect of: 1) various management scenarios at reducing

brucellosis in Yellowstone bison; and 2) the effectiveness of selective management practices aimed at potentially infectious female Yellowstone bison.

More recently, a Bayesian state-space model was developed in conjunction with monitoring data to forecast population dynamics and the usefulness of brucellosis management strategies of Yellowstone bison (Hobbs et al. 2013). Brucellosis control strategies were evaluated based on a strategy's ability to meet management's goals, such as cutting transmission probability by 50% annually and reducing seroprevalence levels below 40% for adult females. Control strategies targeted 200 animals per year for up to five years, and were the following: 1) no action, 2) removing seropositive females, 3) removing seronegative animals, 4) harvesting animals at the boundary, and 5) vaccination. Results indicated by the fifth year there was a 19 fold increase in the probability of reducing brucellosis seroprevalence below 40%, when seropositive females were removed compared to a no action strategy. For vaccination, there was a two-fold increase in the probability of reducing seroprevalence below 40% compared to a no action strategy. Despite these results, the chances of reducing brucellosis seroprevalence approximately 10% in five years through culling of seropositives and vaccination were only 42% and 5%, respectively. These estimates were even lower when more uncertainty was included in the model, such as movement of animals to boundary locations where they could be vaccinated or selectively removed.

Management Costs: The primary goal of the proposed project is to evaluate the cost-effectiveness of various management strategies for control of brucellosis in bison. Brucellosis mitigation strategies in wildlife are a requirement to maintain class free disease status and were part of the 2010 APHIS Interim Rule and Montana's Interagency Bison Management Plan (USDA 2010; USDI 2008). Most of the brucellosis control efforts in Yellowstone bison have focused on spatial and temporal separation from cattle, culling without testing, and in rare occasions, vaccination at capture facilities (White et al. 2011). While these efforts have been successful in preventing brucellosis transmission between bison and cattle (Kilpatrick et al. 2009), they have not been successful in reducing prevalence of the disease in Yellowstone bison (White et al. 2011). The inability to reduce brucellosis prevalence in Yellowstone bison is complicated by other wildlife sources of brucellosis, availability of resources, effectiveness of management strategies, and consistency in implementation of management strategies. In addition, it has been suggested through a Bayesian model that management efforts proposed by the Interagency Bison Management Plan will increase the number of bison exiting the park in the future (Geremia et al., 2011).

Several studies have estimated the effectiveness of various management strategies in reducing brucellosis in bison (Dobson and Meagher 1996; Ebinger et al. 2011; Hobbs et al. 2013; Peterson et al. 1991; Treanor et al. 2010). No known literature exists on the cost-effectiveness of these strategies in Yellowstone bison. One recent assessment focused on the costs and benefits to society of controlling brucellosis in elk through vaccination, test and slaughter, or the use of feed grounds to reduce economic losses associated with cattle outbreaks. Results of the study

indicated costs exceeded benefits for each activity—with elk feed grounds having the least net negative benefit (Kauffman et al. 2011). Another assessment calculated the cost of brucellosis prevention activities to a 400 head cow-calf operation using a whole farm and partial budgeting scheme (Roberts et al. 2012). Researchers determined the cost to the producer for hazing elk by the Wyoming Game and Fish Department was cheapest ($0), followed by fencing a haystack ($103), adult booster vaccination of cattle ($797), spaying heifers ($2365), hiring a rider ($14,194), and delayed grazing ($15,189) (Roberts et al. 2012). These numbers did not include the costs borne by the Wyoming Fish and Game. This report also indicated producers would be more likely to pay for costly prevention activities if the risk for brucellosis transmission were substantially higher, for instance greater than 50%. The costs of management strategies in bison are expected to vary from that of elk and cattle. Thus, the purpose of this study plan will be to develop a modeling strategy that determines the cost effectiveness of management strategies in bison after accounting for biological efficacy, transmission dynamics between wildlife and cattle, and the ability to implement those strategies in Yellowstone bison.

Goal III: Cost Assessment of developing an effective domestic livestock vaccine

Vaccination Background: In the United States control and prevention of brucellosis in domestic cattle herds has relied heavily on vaccination (Ragan 2002). Early eradication efforts used the vaccine *Brucella abortus* strain 19 (S19) in cattle, but due to its cross reactivity on serological tests, and high abortifacient effects it was replaced by the vaccine *Brucella abortus* strain 51 (RB51). Vaccine RB51 was an improvement over S19 because it was less of an abortifacient (Palmer et al. 1996). In addition, vaccinated animals remained seronegative on standard diagnostic tests which prevented vaccinated animals from being removed during test and removal procedures (Stevens et al. 1995). Currently RB51 calfhood vaccination is mandatory in female domestic cattle residing in the designated surveillance area, to prevent potential spillover from brucellosis endemic wildlife. Despite this preventative measure, seven confirmed cases of brucellosis have been reported in Montana, Wyoming, and Idaho since 2011 (USDA 2013). Detection of brucellosis positive cattle herds will likely continue until brucellosis is controlled in GYA wildlife or a more effective brucellosis vaccine is developed.

Livestock and Wildlife Vaccination: The literature on livestock and wildlife vaccination is extensive. The following brief discussion is not an exhaustive review of the literature. Both simulation and challenge studies have indicated the current vaccine is not sufficient to eliminate brucellosis in wildlife reservoirs (Kreeger et al. 2002; Treanor et al. 2010; Ebinger et al. 2011; Hobbs et al. 2013; Olsen and Johnson 2012) or to provide complete protection to cattle (Olsen 2000; Poester et al. 2006). In most efficacy studies, RB51 vaccines have been shown to be more effective at reducing abortion rates rather than infection rates (Olsen 2000; Olsen et al. 2003; Olsen and Johnson 2012). For cattle, a high dosage of RB51 reduced the incidence of abortion by ~75% but only reduced the heifer infection rate by ~31% (Olsen 2000). Cumulative studies in bison have indicated RB51 was effective at lowering abortion rates by 55% and uterine infections by 45% (Olsen and Johnson 2012). However, rates of recovery of the challenge strain

were 80-100% in bison calves given either a single calfhood vaccine or yearling booster shot, which indicated the vaccine did not prevent infection of individual animals (Olsen and Johnson 2013). Failure of RB51 in elk was not only limited to the inability to block the establishment of infection but also abortion prevention (Kreeger et al. 2002; Cook et al. 2002). Vaccine efficacy estimates for reducing abortion rates in elk vaccinated with RB51 ranged from 0-25% (Kreeger et al. 2002; Cook et al. 2002). Collectively these studies confirm there is a need for a vaccine capable of protecting both cattle and wildlife from establishment of *Brucella abortus* infection.

Considerations for development of a new vaccine should include protection from infection, detectability on serological tests, immunological indicators that correlate with immune protection, reduced abortive effects, and cross-species protection. The method of vaccine delivery, dose-regimen, and timing of vaccination is also important. Oral and remote vaccine delivery systems have been assessed and compared to manual vaccination in experimental studies of bison, cattle, and elk and may have an advantage for use in free-ranging animals (Elzer 1998; Davis et al. 1991; Cook et al. 2002; Olsen and Johnson 2012). Booster vaccination also shows promise over single calfhood vaccination. A recent assessment indicated yearling bison boostered with RB51 had lower abortion and uterine infection rates, as well as tissue colonization by bacteria, compared to yearling bison given a single calfhood shot (Olsen and Johnson 2012).

One potential vaccine candidate on the horizon is the DNA vaccine containing *Brucella* bp26 and trigger factor genes (Yang et al. 2005; Clapp et al. 2011). *Brucella* is an intracellular pathogen, where cell mediated immunity has been shown to be important in providing host-protection against *Brucella* invasion (Oliveira et al. 1998). One of the potential benefits of a DNA vaccine is the stimulation of both cell-mediated and humoral immune responses (WHO 2013), a feature that is lacking with current commercial brucellosis vaccines. The ability of the DNA vaccine to elicit a Th-1 cell-mediated response was recently shown using eight bison challenged with brucellosis (Clapp et al. 2011). While the results of this study were encouraging, future field studies are needed to determine if this vaccine is capable of reducing brucellosis colonization in ruminants. Other vaccines that may be of interest are those that have been tested by the Russian Federation: *B. abortus* 82, *B. abortus* 82-PS, and *B. abortus* 75/79-AB. *Brucella abortus* 82 has been used since 1974 in Russian cattle herds and is believed to have played a significant role in reducing rates of brucellosis infection (Salmakov et al. 2010). There is a need however, for large scale comparative field studies to determine if the Russian vaccines are more efficacious than RB51 at reducing brucellosis infection rates in domestic cattle populations.

Vaccine Cost Assessment: The final goal of this study is to assess the costs associated with developing a brucellosis livestock vaccine. The ideal vaccine should demonstrate efficacy and effectiveness at reducing the brucellosis abortion rate, maternal infection rate, and fetal infection rate in both wildlife and cattle. Previous studies have assessed the costs and benefits of vaccination in cattle in terms of a reduction in human health risk (Roth et al. 2003), cow infection rates (Xie and Horan 2009), and cow-calf economic losses (Roberts et al. 2012). A

recent report assessed the total cost, annual cost, and break-even level of effectiveness of vaccination using a specific herd example under two different adult booster vaccination strategies (Roberts et al. 2012). Results of this study were particularly useful for producers weighing the costs and benefits of different vaccination strategies, although the costs were assessed in terms of the producer and not society. This cost-assessment also did not determine the financial burden associated with developing and implementing a new vaccine. Thus, one of our objectives will be to estimate the costs associated with developing a commercial vaccine that has the potential to successfully reduce brucellosis in domestic livestock and wildlife.

Analytical Approach

A primary objective of this study is to evaluate the effectiveness and costs of management strategies of brucellosis in Yellowstone bison with a particular focus on the impacts of these strategies on infection rates in domesticated cattle in the GYA. Evaluating the benefits of management strategies is contentious because of the controversial nature of bison leaving the park and the differing public views about the value of free-ranging bison versus the sanctity of private property rights and the potential for cattle infection. The approach taken here is to estimate the costs using typical cost management estimation methods. We will also evaluate the biological outcomes of the management strategies, but we will not attempt to monetize the wildlife benefit of those outcomes. Placing monetary values on the wildlife outcomes is prohibitively controversial and would require so much speculation that it would not productively contribute to the discussion.

The analytical model will be constructed in a manner that it will be useful over an extended period to such interested parties as National Park Service personnel, other researchers, and public interest groups. The model will be sufficiently transparent to be understandable and easily updated as new information becomes available. Written materials as well as discussions will be offered so that the model can be widely used beyond this study.

All models are abstraction from reality, as is this effort. The model will be designed to capture the important elements of brucellosis management and to abstract from those of less importance. If the model is to be widely used it must be sophisticated enough to capture the essential elements of concern, but simple and transparent enough to be accessible to interested parties.

A central focus of the management outcomes of the model requires capturing the dynamics of brucellosis infection across bison, elk, and cattle. Different management strategies will affect the dynamics of the brucellosis infection and thereby the costs.

Suppression and Outbreak Costs

Costs will be estimated using traditional budgeting approaches that identify each activity required in the management process and then budget the costs of each activity. While some of the cost information is readily available, other information will be developed through interviews

with knowledgeable personnel such as National Park Service personnel, ranchers, and veterinarians. The management costs will be incurred over an extended period of time and so the analysis will include the timing of costs and will be summarized as present values.

Dynamic Brucellosis Model

The dynamic nature of brucellosis will require an explicitly dynamic model. While there are multiple approaches to this problem, the approach that appears to best capture the dynamics as well as provide the desired information on outcomes is a Markov Chain model (see any edition of Hillier and Lieberman for an introductory discussion of Markov Chains or Howard (1971) for a more advanced treatment). A Markov Chain type of model can capture the stochastic nature of infections, as well as the dynamics of changing levels of infections (Longini et al. 1999; Zipkin et al. 2010; Yaesoubi and Cohen 2011). The mathematical appendix to the study plan contains a simple discussion of the basic elements of a Markov Chain model. While the Markov Chain model appears to be the most appropriate approach at this time, further investigation may reveal a preferred alternative. (Any major change in the modeling approach will be discussed with the National Park Service.)

Because of the limits on the way probabilistic outcomes can be accommodated in a continuous Markov Chain model, a stochastic discrete model will likely be chosen. States of nature will be identified that describe different possible situations. A state of nature could include the brucellosis infection level in each species, age composition of each species, population of each species, and so forth. Multiple states are defined so that the multitude of possible outcomes is reasonably approximated. The next step is to develop estimates of the probabilities of moving between states over a single time period. These transition probabilities depend not only on the leaving and entering state but also on the management strategy employed. Given that we know the current state and the transition probabilities, the probability of being in any state after a chosen number of periods can be calculated. This approach then allows the probabilistic prediction of outcomes given an initial state, a management strategy, and the associated transition probabilities.

The development of state transition probabilities requires a large amount of information. The information required includes infection rates between and within species by age composition, changing age composition by species, changing population by species, and effects of management strategy on infection rates. To the extent possible the necessary information used in the modeling will be based upon the published literature or estimated from available data. In instances where required information is not available, we will call on experts with substantial knowledge and experience to help develop the required information. Of course, we will be especially concerned about sensitivity of the outcomes to the opinion based information.

Parameter uncertainty (e.g. vaccine efficacy) can be either explicitly modeled in the transition probability process or by sensitivity analysis either in the underlying parameters or the transition

probabilities. Explicitly modeling the parameter uncertainty requires knowledge of the probability distribution of the parameters. The approach to evaluating parameter uncertainty will depend on the available information and the importance of the parameters to the outcome.

Use of Markov Chain models is particularly subject to criticism because the outcomes are difficult to validate. These models are often used to predict long term effects, and usually there are not long term data sets that can be used to validate the model—if long term robust data sets existed another approach would likely be taken. Every effort will be made to validate the model to the extent possible. For example, the Monte Carlo Markov Chain model approach (Brooks 1998; Hobbs et al. 2013) has potential to assist in the validation process.

In the current context, the Markov Chain approach allows the forecast of changes in brucellosis infection levels over time for a particular strategy. An adaptive management approach can be incorporated by changing the management strategy, leading to an adjustment in the transition probabilities, as infection rate levels or other variables reach designated thresholds.

It is unlikely that it is possible to eradicate a disease in the sense that the probability of a future infection is absolutely zero. From a practical modeling perspective, some small probability of future infection with no current infection could be defined as eradication. In this practical sense of eradication, the model output provides the desired information on eradication. Furthermore, the model can be used to provide a probability distribution for the time it will take to reach eradication.

Management strategies to be investigated will be developed jointly by National Park Service personnel, National Park Service appointees, and the principal investigators. In a similar manner, an expert Advisory Group will assist in developing the necessary information for development of the state transition probabilities that is unavailable from existing published sources or cannot be estimated due to lack of data. In some cases the analysis will identify critical pieces of missing information. While those missing elements will initially be determined by expert opinions, as more rigorously developed information becomes available it can be incorporated into the model. One of the benefits of this approach is that it forces the recognition of important information and it does not mask the need for that information with opaque model structure or inflexibilities. After the management strategies are identified, costs are estimated, and the probabilities of cattle infection are estimated with the Markov chain model, both costs of suppression and outbreak can be calculated for each management strategy. The example appendix provides an illustrative example of a hypothetical Markov chain model that calculates the effectiveness of brucellosis management strategies in cattle and wildlife.

Cost Estimator for Brucellosis Management Strategies

A user-friendly computerized cost estimator program will be made available to the National Park Service to assist in the selection of a cost-effective brucellosis management strategy. Below is a simplified representation of the program, which will be based on the Markov Chain process.

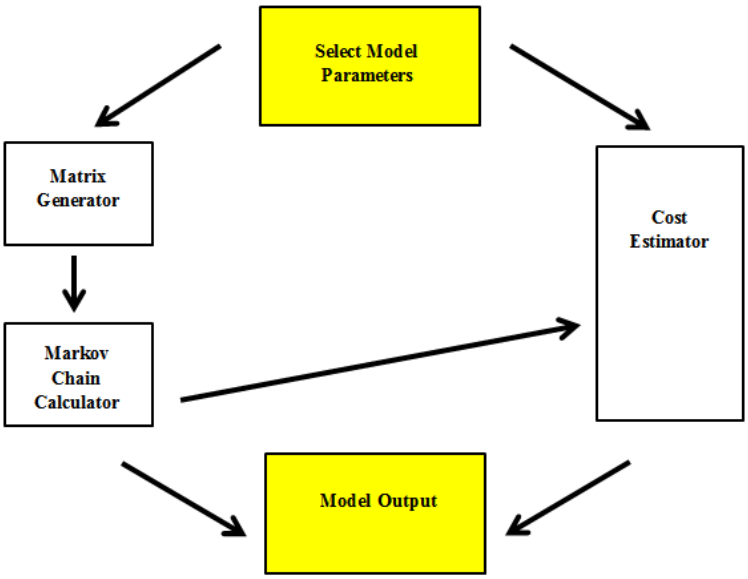


Figure 1: Computerized Cost Estimator for Brucellosis Management Strategies

Program users will select model parameter values through a drop down menu or form. Model parameter values will be selected for those variables to be identified in the proposed project as influential in the transmission and prevalence dynamics of brucellosis in bison, elk, and cattle herds. Efficacy estimates associated with the management strategies to be compared will also be chosen. After the model parameter values are selected by the user, the Matrix Generator will produce the corresponding transition probability matrix. A baseline scenario will be specified for comparison to the management strategy of interest. For the user-specified number of periods (or iterations), the Markov Chain Calculator will generate transition probabilities for brucellosis infection in the baseline and management strategy scenarios. Cost estimates will be combined with the probabilities from the Markov Chain Calculator to obtain expected future costs. The cost estimates will reflect the federal, state, local, and ranch-level costs associated with each scenario under consideration. The output generated for the user will describe the efficacy of the management strategy and will also compare the present value of the expected cost estimates associated with the baseline and management strategy scenarios.

Vaccine Costs

Cost of developing drugs or vaccines vary widely depending on a broad range of factors, many of which are stochastic. We have retained the services of Dr. Winship, who has been involved in several drug and vaccine development efforts. Costs will be estimated for each step in the development and approval process. This approach will ease the difficulty of estimating the remaining cost of vaccines that are currently partially developed. It is important to recognize that the estimates to be developed in this portion of the project may be considerably higher or lower than the actual costs of the vaccines under consideration. Many vaccines are not successfully

commercialized even though they may be technically feasible. Some vaccines that appear to have high potential initially are later abandoned for a variety of reasons. The vaccine development process will be described, cost estimates developed, and the probability of success discussed.

Summary, Future Work, and Expected Outcomes

In the proposed project, the primary focus of our efforts will be the following:

- Develop estimates of the costs of brucellosis outbreaks in Montana cattle. The costs of such an outbreak will depend on the protocol or management strategy in effect for responding to the outbreak. The calculations in this portion of our analysis will be made using the provisions of the 2010 APHIS Interim Rule. Relevant cost categories for federal, state, and private entities that will be considered include (but will not necessarily be limited to) identification costs, costs associated with extended quarantine of infected herds, expenses incurred from slaughtering and disposing of infected animals, and the costs of tracing back infected animals to their herd of origin to determine if those are infected with brucellosis. The costs of an outbreak will depend on such factors as the size of the infected herd, the history of the breeding animals in the herd, market prices of cattle at the time of the infection, the duration of the quarantine period, and so forth. Information to develop the cost estimates in this portion of the project will be gathered from the existing literature, veterinarians who have dealt with brucellosis outbreaks, APHIS experts, and cattle producers.

- Develop a framework for estimating the impacts/effectiveness and costs of specified bison brucellosis management activities. At present, the possible management tools to be considered include vaccination, test and removal, hazing, hunting, and fertility control. The objectives to be assessed include eradication of brucellosis (if possible), reductions in the prevalence of infection, and managing the costs of reducing transmission of brucellosis between bison (or elk) and cattle by maintaining or increasing separation. The actual management strategies to be evaluated will be developed with input from the National Park Service and their nominees. At this point in time, the most appropriate approach for assessing the effectiveness and costs of specified management activities appears to be to develop a Markov Chain model. We believe that this will be the first model of this type that includes multiple species. Single species models such as Hobbs et al. (2013) will provide a valuable foundation.

- Estimate the costs of developing an effective vaccine for domestic cattle that may also be effective in bison and elk. The vaccine development process will be described, cost estimates will be developed for each step in the development and approval process and the probability of success will be discussed. It is important to note that—while we have retained the services of an individual who has substantial experience in estimating the costs of drug development—any such estimates may be considerably larger or smaller than the actual costs of developing any given drug.

- Provide documentation and training to National Park Service personnel on the use of the computer model. This training will allow the National Park Service to assess the variety of scenarios that will be of interest to parties involved in the policy discussions regarding management of bison and the methods that might be used to address the problems associated with brucellosis.

The output from this project will include a report to the National Park Service that assesses the cost and efficacy of various management strategies and a computer model that will be accessible to individuals with modest expertise in modeling.

Example Appendix

Although Markov Chains are well known within the field of operations research, the tool may not be familiar to those without an operations research background. In this appendix, we present and develop three examples designed to illustrate the use of the Markov Chain in the context of Brucellosis management. The examples are highly simplified, but do get progressively more complex. All parameter values in the examples are strictly hypothetical and are not intended to be accurate representations of reality. The model to be developed in the proposed project would be much larger and more complex than the examples.

Example 1: The first example considers infection probabilities in a single species. Uncertainty regarding current and future infection is modeled as being dichotomous, with the species either being infected (State 1, or S_1) or not infected (State 2, or S_2) as reflected in the table below.

State	Status
S_1	Infected
S_2	Not Infected

The Markov Chain approach requires the specification of a *transition probability matrix*, which provides the probabilities of transitioning from one state to another between the current period and the next period. For this example, suppose the transition probability matrix is

(1)
$$P = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} .8 & .2 \\ .1 & .9 \end{pmatrix} \end{array}$$

The first entry in the 2x2 matrix (.8) is interpreted as the probability that if a species is infected in the current period (that is, it is in S_1) it will also be infected next period (it is in S_1 again). The second value in the first row indicates that there is a 20 percent probability that if the species is infected in the current period, it will not be infected in the next period. Note that because the species must either be infected or not infected in the next period, the two values in the first row (and each of the other rows as well) must sum to 1.0. The first entry in the second row (.1) indicates that if the species is not infected in the initial period, there is a 10 percent probability that it will be infected in the ensuing period. And the second entry in the second row (.9) suggests that if the species is not infected initially, then the probability that it will not be infected in the next period is 90 percent.[1]

[1] It may be helpful to note that the rows in the 2x2 matrix above represent the state of the process in the current period and the columns represent the state in the future period of interest. In the matrix in expression (1), the columns represent the state of the process in the next period. In the matrixes to follow, the columns sometimes represent the state of the process further into the future.

The Markov Chain approach can be used to provide information on (i) the state of infection in the species after any given number of periods and (ii) the very long-term (or steady state) likelihood of infection. Figure 1 is a "tree" diagram that provides a visual depiction of the initial steps in the Markov Chain process. In the diagram "I" indicates the state of the world in which the species is infected, and "N" indicates the state wherein the species is not infected.

The interpretation of the first two columns in the tree diagram is the same as in the 2x2 matrix above. The very first column in the diagram indicates that, initially, the species may be either infected or not infected. In moving from the first column to the second column (or from period 0 to period 1), we see by looking at the top portion of the tree, that if the species is infected in period 0, then there is an 80 percent probability that it will also be infected in period 1 and a 20 percent chance it will not be infected in period 1. From the bottom portion of the tree, if the species is not infected in period 0 then there is a 10 percent probability it will be infected in period 1 and a 90 percent chance it will not be infected in period 1.

The third column in the tree diagram can be used to determine the transition probabilities between the current period (period 0) and two periods in the future (period 2). An important underlying assumption (in all three examples and, in general for Markov Chains) is that the transition probabilities between any two contiguous periods are constant. In other words, to this point in the discussion, the matrix in expression (1) represents the transition probabilities between the current period and the next period. It can also, however, represent the transition probabilities between, say periods 3 and 4, periods 8 and 9, and, in general, periods t and t+1.

Consider first the top-most branch in the tree. Here, the species is infected in all three periods. The probability that if the species is infected in the initial period, it will also be infected in each of the next two periods is the probability of going from the infected state to the infected state twice, or $0.8x0.8 = (0.8)^2 = 0.64$ (or 64 percent). The next highest branch in the tree can be used to determine the probability that if the species is infected in period 0, it will then be infected in period 1 and will not being infected in period 2. This probability is $0.8x0.2 = 0.16$ (or 16 percent). The interpretation of the other branches is exactly analogous. For example, the bottom branch (on the bottom portion of the tree) can be used to determine the probability that if the species is not infected in period 0, then it will not be infected in either period 1 or period 2. This probability is the probability of going from not infected in period 0 to not infected in period 1 and then to not infected again in period 2, or $0.9x0.9 = 0.81$.[2]

A question of interest is "If the species in the example is infected today (period 0), then what is the probability that it will also be infected two periods in the future?" From the top portion of the tree diagram, it can be seen that there are two ways for that to happen—the species could be infected in all three periods, or the species could be infected in period 0, not infected in period 1, and then infected again in period 2. The probability of the first of these is $0.8x0.8 = 0.64$, and

[2] It is important to note that the information in the transition probability matrix does not provide any information on the probability that the species is initially infected (or not infected).

the probability of the second is 0.2x0.1 = 0.02. The sum of these two—0.64 + 0.02 = 0.66 (or 66 percent) is the answer to the question posed above. Similarly, the probability that if a species is infected today, it will not be infected two periods in the future is 0.8x0.2 + 0.2x0.9 = 0.34. Note that the sum of these two probabilities is 1.0, which is intuitive because if the species is infected today, it must be either infected or not infected two periods into the future.

The tree diagram could be expanded to include additional periods, but would quickly have too many branches to display conveniently on one page—Period 3 would have 16 nodes, Period 4 would have 32 and so forth. Fortunately, matrix algebra methods provide a much more space-efficient method of displaying the results of interest for this problem.[3] It can be shown that if the 2x2 matrix in expression (1) above is multiplied by itself, the result is

$$(2) \qquad \text{PxP} = \begin{pmatrix} .8 & .2 \\ .1 & .9 \end{pmatrix} \begin{pmatrix} .8 & .2 \\ .1 & .9 \end{pmatrix} = \text{P}^2 = \begin{array}{c} \\ S_1 \\ S_2 \end{array} \begin{array}{c} \begin{array}{cc} S_1 & S_2 \end{array} \\ \begin{pmatrix} .66 & .34 \\ .17 & .83 \end{pmatrix} \end{array}$$

The value of the first entry in the first row of the P^2 matrix represents the probability that if the species is infected in the current period, it will also be infected two periods later in period 2. This value, 0.66 (or 66 percent), is the same as the value obtained from the tree diagram in the discussion above. The value of the second entry in the first row is the probability that if the species is infected in the current period, it will not be infected two periods later. This value—0.34—is also the same as the value obtained from the tree diagram above.

The matrix multiplication approach can be used to determine the probability of being in a particular state—infected or not infected—after T periods by going through analogous calculations as those above. Below are results for T=4, 8, 32, and 64.

$$(3) \quad P^4 = P^2 \square P^2 = \begin{pmatrix} .49 & .51 \\ .25 & .75 \end{pmatrix} \qquad P^8 = \begin{pmatrix} .37 & .63 \\ .31 & .69 \end{pmatrix} \qquad P^{32} = \begin{pmatrix} .33 & .67 \\ .33 & .67 \end{pmatrix} \qquad P^{64} = \begin{pmatrix} .33 & .67 \\ .33 & .67 \end{pmatrix}$$

The interpretation is exactly analogous to the interpretation of the P^2 matrix. For example, if the current population is infected, the probability of no infection after four periods is 0.51, or 51 percent. Similarly, if the current population is not infected, the probability of infection after eight periods is 0.31, or 31 percent. Note that in each of these matrices, every row sums to 1.00. This is because if, e.g., the species is currently infected, it must be either infected or not infected after T periods.

It is noteworthy that (i) in both P^{32} and P^{64} the first and second rows are identical, and (ii) the values in the P^{32} and P^{64} matrices are exactly the same. These two observations demonstrate two important properties of well-behaved Markov transitional probability matrices. The first

[3] For a primer on matrix multiplication see *Math is Fun, Advanced* at http://www.mathsisfun.com/algebra/matrix-multiplying.html.

observation indicates that regardless of whether the species is initially infected or not infected, after an extended period of time the probability of infection is 33 percent, and the probability of not being infected is 67 percent. In other words, if the process goes on for many periods, the initial state becomes irrelevant. The second observation suggests that after a point, more time can pass and the probabilities do not change. That is, a steady state has been attained. In this example, the steady state is represented by the 1x2 matrix

(4) $$Steady\ State = \begin{pmatrix} .33 & .67 \end{pmatrix}$$

The interpretation of this steady state matrix is that in the long term about 33 percent of the time the species will be infected and about 67 percent of the time there will be no infection.

Example 2: In this example, there are two species—wildlife and cattle, each of which may be infected or not infected. The table below shows the four possible infection combinations in any given period for this example.

	Status	
State	Wildlife	Cattle
S_1	Infected	Infected
S_2	Infected	Not Infected
S_3	Not Infected	Infected
S_4	Not Infected	Not Infected

Assume the transition probability matrix for this example is

(5) $$P = \begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \\ S_4 \end{array} \begin{array}{c} \begin{array}{cccc} S_1 & S_2 & S_3 & S_4 \end{array} \\ \begin{pmatrix} .80 & .17 & .02 & .01 \\ .40 & .57 & .02 & .01 \\ .20 & .20 & .20 & .40 \\ .01 & .01 & .01 & .97 \end{pmatrix} \end{array}$$

The interpretations of the values in this matrix are analogous to the first example. For example, the first value in the first row indicates that if both wildlife and cattle are currently infected, then there is an 80 percent probability that both will be infected in the next period. As another example, the fourth entry in the third row suggests that if wildlife are not infected and cattle are infected in the initial period, then the probability is 40 percent that neither species will be infected in the next period. As in the previous example, the four values in each row sum to 1.00, indicating again that whatever the state of the two species in a given period, one period later the species must be in one of the four possible states.

Again, the matrix multiplication approach provides a concise framework to determine the probability of being in each of the four states after T periods (given a starting state). The probability transition matrices after, e.g., T=2, 8, and 32 periods are

$$(6)\quad P^{2} = \begin{pmatrix} .712 & .237 & .024 & .027 \\ .552 & .397 & .024 & .027 \\ .284 & .192 & .052 & .0472 \\ .024 & .019 & .012 & .945 \end{pmatrix} \quad P^{8} = \begin{pmatrix} .594 & .258 & .023 & .126 \\ .593 & .258 & .023 & .126 \\ .349 & .157 & .019 & .476 \\ .108 & .057 & .014 & .822 \end{pmatrix} \quad P^{32} = \begin{pmatrix} .449 & .198 & .020 & .333 \\ .449 & .198 & .020 & .333 \\ .368 & .164 & .019 & .449 \\ .288 & .131 & .017 & .564 \end{pmatrix}$$

Note again that the sum of every row in every one of the transition probability matrices above is 1.000. This reflects the fact that regardless of the status of the two species initially, after any arbitrary number of periods, the status of the two species must be one of the four specified in the table. To demonstrate the interpretation of the values in the above matrices, consider two examples. If neither species is currently infected (S_4), the probability that both will be infected after eight periods (S_1) is 10.8 percent. Alternatively, if neither species is currently infected (S_4), the probability that neither will be infected after 32 periods (S_4 again) is 56.4 percent. Because all the values in each column of the P^{32} matrix are not identical, we know that after 32 periods the system has not yet converged to a steady state.

Using methods discussed in the Mathematical Appendix that follows, the steady state for this example is

$$(7)\quad \textit{Steady State} = \begin{pmatrix} .377 & .168 & .019 & .436 \end{pmatrix}$$

This steady state matrix tells us that—regardless of the initial infection status of the two species in this example—in the long term the probability that both will be infected is about 38 percent, whereas the probability that neither species will be infected is about 44 percent. Further, note that wildlife are infected in either state S_1 or state S_2. This suggests that the probability wildlife will be infected in the long-run is 0.377 + 0.168 = 0.545, or 54.5 percent. Similarly, noting that livestock are infected in either S_1 or S_3, the long-run probability that livestock will be infected is 0.377 + 0.019 = 0.396, or 39.6 percent.

A primary purpose of the proposed project is to estimate the costs of various brucellosis management plans. The Markov Chain approach described to this point provides information on how infections will evolve over time, given a transition probability matrix. To illustrate how the costs and benefits of different management plans will be estimated, suppose the transition probability matrix discussed to this point in the second example represents the situation in which the management plan currently in place involves no vaccination of cattle. Further, suppose there are 1,000 head of cattle in the herd and that if the cattle become infected, they are slaughtered, disposed of, and a replaced by a new (identical) herd at a total cost of $1 million (an average value of $1,000 per animal).

Now, consider a management plan in which a moderately effective vaccine is administered to the cattle every period. Suppose the cost of administering the vaccine is $10 per animal, or $10,000 per year for the herd. For this example, assume this cost includes the costs of the vaccine, veterinarian services, and the rancher's costs. Assume also, that as under the previous plan, if the cattle are infected, they are slaughtered and replaced at a cost of $1,000,000.

Assume that the revised transition probability matrix associated with this new management plan is

$$PR = \begin{pmatrix} .10 & .87 & .02 & .01 \\ .05 & .92 & .02 & .01 \\ .15 & .20 & .2 & .45 \\ .01 & .01 & .01 & .97 \end{pmatrix} \tag{8}$$

The primary changes in the transition probability matrix are in the four values in the northwest corner of the matrix. What is the interpretation of these changes? Regarding the change in the first value in the first row (from 0.80 to 0.10), with the new management strategy, the probability of transitioning from the state in which both species are infected in the current period (S_1) to that same state in the ensuing period is greatly reduced. This reduction is largely offset by an increase in the likelihood of being in the state where wildlife are infected and cattle are not infected (S_2). The substantial reduction in the value of the first element in the second row (from 0.40 to 0.05) indicates that the likelihood of going from the state in which the wildlife are infected and the livestock are not infected (S_2) in period 0 to the state in period 1 in which both the cattle and the livestock are infected (S_1) is greatly reduced by the application of the vaccine. At the same time, as indicated by the increased value of the second entry in the second row (from 0.57 to 0.92), the probability of going from the state in which the wildlife are infected and the livestock are not infected (S_2) to that same state one period later is increased.

The steady state for this revised matrix is

$$Steady\ StateR = \begin{pmatrix} .035 & .489 & .019 & .457 \end{pmatrix} \tag{9}$$

Note that in the long run, the probability of cattle being infected is now 0.035 + 0.019 = 0.054. Thus, this probability has fallen from almost 40 percent to 5.4 percent. Note also that the long-run probability of wildlife being infected has fallen from 54.5 to 52.4 percent. In this particular example, the drop in the probability of infection was much larger in cattle, as would be expected given the focus of the management plan considered. Of course, the management focus could be on both species or just on wildlife. Either of these can be accommodated by the approach we propose to employ.

What are the costs and benefits of the revised management plan? In this example, the costs are the vaccination costs of $10,000, which are incurred every period. The benefits take the form of

a reduced probability of livestock infection, which means livestock producers (and/or taxpayers) will less frequently incur the costs associated with slaughter. How might the dollar value of these benefits be calculated? Suppose we know the initial state of infection of the two species. If we are initially in S_1 (both wildlife and cattle are infected), then the probability of livestock being infected in period 1 has fallen from 0.82 (= 0.80 + 0.02) to 0.12 (= 0.10 + 0.02) and the expected costs of infection fall from 0.82x$1,000,000 = $820,000 to 0.12x$1,000,000 = $120,000, a cost reduction of $700,000. Similarly, if we are initially in S_2 (wildlife infected, cattle not infected) in period 0, then the expected costs of cattle infection fall from 0.42x$1,000,000 = $420,000 to 0.07x$1,000,000 = $70,000, which represents a cost reduction of $350,000. If we are currently in S_3, the cost reduction is $230,000 (= $400,000 - $170,000). There are no changes in the probabilities in the fourth row of the transition matrix, so there are no cost reductions if neither species is initially infected.

The expected benefits for the second period are obtained by finding the difference (for each initial state) between the probability of livestock infection from the P^2 matrix in expression (6) above, and the corresponding probability from the analogous PR^2 matrix (not shown). This difference can be calculated for each future period. The present value of all these future financial flows (both costs and benefits) will then be summed to calculate the total net present value of the of the revised management plan.

Example 3: This example also includes a wildlife species and cattle but wildlife now has three levels of infection—None, Low, and High. The six possible states in this example are defined in the table below.

State	Wildlife	Cattle
S_1	No Infection	Not Infected
S_2	Low Infection	Not Infected
S_3	High Infection	Not Infected
S_4	No Infection	Infected
S_5	Low Infection	Infected
S_6	High Infection	Infected

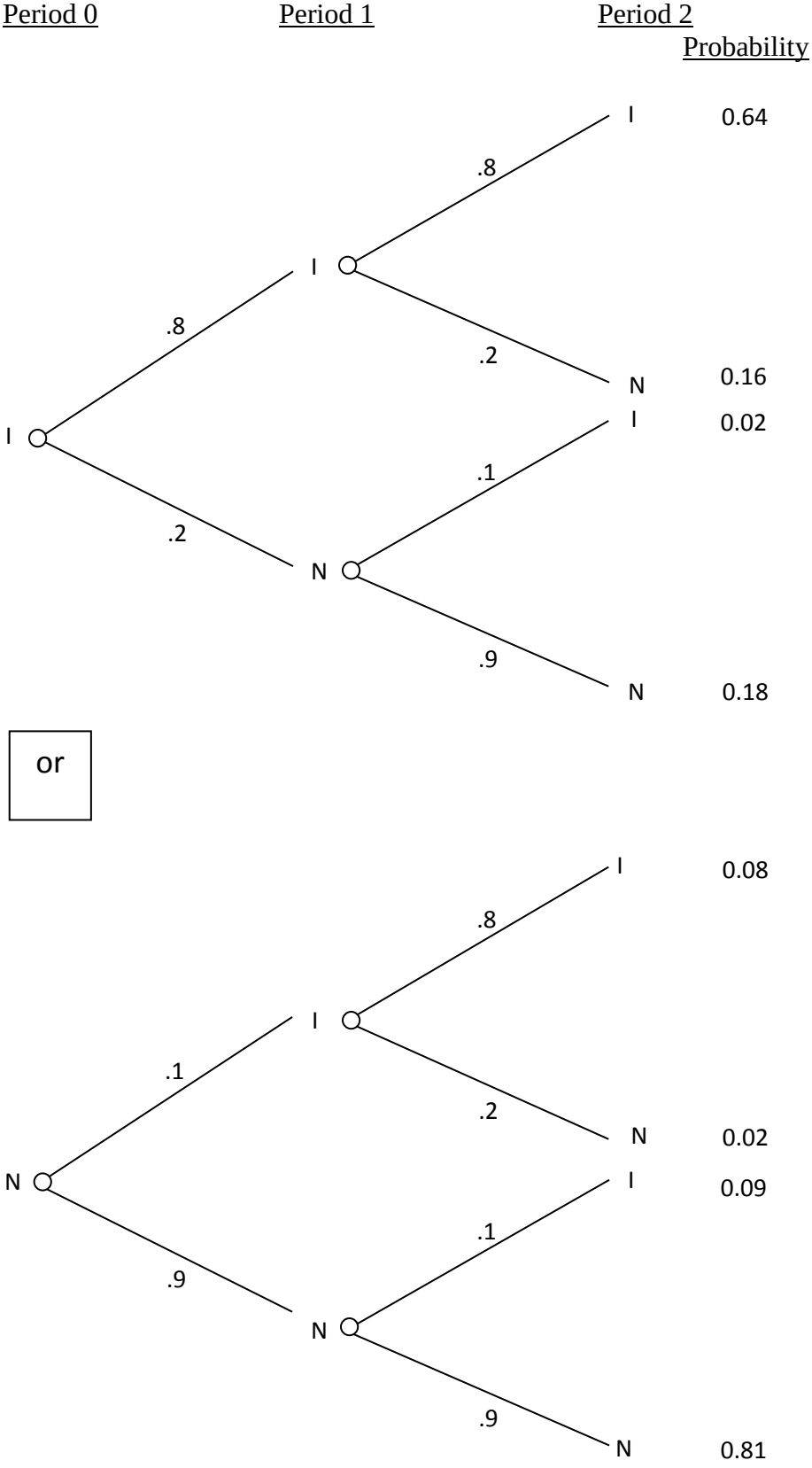
Assume that the transition probability matrix for this example is

(10)
$$P = \begin{pmatrix} .900 & .040 & .030 & .015 & .010 & .005 \\ .300 & .400 & .100 & .060 & .100 & .040 \\ .050 & .200 & .300 & .050 & .100 & .300 \\ .400 & .200 & .100 & .100 & .100 & .100 \\ .100 & .100 & .100 & .200 & .300 & .200 \\ .100 & .100 & .200 & .200 & .200 & .200 \end{pmatrix}$$

The steady state probabilities for this example are

(11) $$\textit{Steady}\ \text{State} = \begin{pmatrix} .657 & .104 & .075 & .048 & .058 & .057 \end{pmatrix}$$

As can be seen, going from a specification of the "infected" state for wildlife as dichotomous to allowing for three levels of infection increases the dimensions of the probability transition matrix. Inclusion of more than two species, indicators of the population size, the age and gender distribution of each species, or any of a number of other important variables will rapidly increase the size of the matrix. Modern computers have the capacity to make the computations necessary to accommodate the complexity of many variables included at different levels.


Period 0
Period 1
Period 2
Probability
I
.8
I
.8
.2
N
0.64
0.16
I
0.02
.1
.2
N
.9
N
0.18
or
I
0.08
.8
I
.1
.2
N
0.02
N
I
0.09
.1
.9
N
.9
N
0.81

Mathematical Appendix

The following discussion outlines and illustrates a potential method to model brucellosis infection. Choice of a final model approach will depend on discussions with the National Park Service and other designated parties. The following is a simple example offered for illustration.

The approach is a Markov Chain. The first step is to define the states of nature. A state of nature is a situation described by a vector of variables. The variables could include the level of brucellosis infection, population level, and gender/age composition for all species. Mathematically

$$s \equiv x$$

Where s is a kx1 vector and s_i designates the i^{th} state which is described by a vector x_i. To illustrate, consider a simple example with two species (A and B) each of which is either not infected or infected, and has low or high population. Then

$$x = [z_{A,Inf}, z_{B,Inf}, z_{A,Pop}, z_{B,Pop}]$$

where the variable notation is apparent, with 0 designating no infection and 1 designating infection, 0 designating low population and 1 high population. If the situation is no infection and low population in both species for state 1 then

$$s_1 \equiv [0,0,0,0]$$

And if state 4 was no infection in A and infection in B, low population in A and high population in B then

$$s_4 \equiv [0,1,0,1]$$

To better approximate continuous variables there may be several levels of population or infection rates considered and the model expanded accordingly.

The conditional (or transition) probability of moving from state i to state j is denoted as

$$p_{ij} = \Pr(s_i \Rightarrow s_j)$$

must be developed for all i and j combinations. These probabilities have all the usual probability properties. Alternatively,

$$p_{ij} = \Pr(s_i \Rightarrow s_j \mid C)$$

where C is a vector of control or management variables. Management variables may include whether to vaccinate, to implement a separation program, to test and remove, etc. Usually the transition probabilities are presented as a square matrix as

$$P = \left[p_{ij} \right]$$

If P is constant over time then after T periods, P^T provides the probability of beginning in state i and ending in state j after T periods. This approach allows estimation of the probabilistic outcomes for any initial state. The number of periods can easily be adjusted so that the time path of adjustments could be viewed. For example if a vaccination program was implemented, the change in infection rates over time could be calculated. The process can include adaptive management if C is constructed as a matrix so that the control or management strategy is dependent on the leaving state in any period.

Given that the P matrix has certain properties, steady state probabilities can be calculated. These are the probabilities of being in each state after a long period of time (convergence as $T \to \infty$). As $P^{T \to \infty}$, the matrix becomes monodesmic where each row vector becomes identical and equal to the steady state vector, π. This means that the steady state vector is independent of the starting state. The steady state vector is reproducible meaning that

$$\pi P = \pi$$
$$\pi (P - I) = 0$$

This system is underidentified, so a unique π cannot be found. The identification problem is solved by recognizing the elements of π sum to 1. The last column of $P - I$ is replaced with 1s and designated M and also the last element in the 0 vector is replaced with a 1 and designated $\tilde{0}$. The steady state vector can then be calculated as

$$\pi M = \tilde{0}$$
$$\pi = \tilde{0} M^{-1}$$

The steady state vector as well as the path to that vector is the management outcome information useful for evaluating different management strategies. Much other information can be obtained from this type of analysis. For example, the expected time until the next infection occurrence for a species (expected first passage time) can be calculated.

The difficult challenge is developing the transition probabilities. There are several possible approaches. To the extent possible these probabilities will be obtained from the literature. The probabilities could also be developed from existing data using a variety of statistical techniques. The techniques include choosing a multivariate distributional form (e.g., Normal, Lognormal, Logistic, Dirichlet, Copula type) with the parameters usually found by moment matching. An alternative approach is the numerically intensive bootstrapping method. Another approach is the direct estimation of the probabilities by nonlinear estimation techniques using available data.

There will be transition probabilities that are unavailable from the literature and for which there are insufficient data for estimation. These probabilities are likely to be based on the judgment of experts until better estimates become available at some future time.

References

Al Dahouk, S., L. D. Sprague, and H. Neubauer, 2013. New developments in the diagnostic procedures for zoonotic brucellosis in humans. *Revue scientifique et technique (International Office of Epizootics)* 32(1):177-188.

Alexander, K. A., J. K. Blackburn, M. E. Vandewalle, R. Pesapane, E. K. Baipoledi, and P. H. Elzer, 2012. Buffalo, bush meat, and the zoonotic threat of brucellosis in Botswana. *PLOS One* 7(3):e32842.

Aune, K., J. C. Rhyan, R. Russell, T. J. Roffe, and B. Corso, 2012. Environmental persistence of *Brucella abortus* in the Greater Yellowstone Area. *Journal of Wildlife Management* 76:253-261.

Brooks, S., 1998. Markov chain Monte Carlo method and its application. *Journal of the Royal Statistical Society: Series D (the Statistician)* 47(1):69-100.

Carvahlo Neta, A. V. C., J. P. Mol, M. N. Xavier, T. A. Paixão, A. P. Lage, and R. L. Santos, 2010. Pathogenesis of bovine brucellosis. *The Veterinary Journal* 184(2):146-155.

Center for Disease Control, 2009. *Brucella suis* infection associated with feral swine hunting three states, 2007—2008. MMWR 58(22); 618-621.

Center for Disease Control, 2014. National notifiable diseases surveillance system – Brucellosis (*Brucella* spp). Retrieved from: http://wwwn.cdc.gov/nndss/script/casedef.aspx?CondYrID=625&DatePub=1/1/2010%2012:00:00%20AM

Center for Disease Control, 2011. Summary of Notifiable Diseases—United States 60(53): 1-118.

Cheville, N. F., D. R. McCullough, and L. R. Paulson, 1998. *Brucellosis in the Greater Yellowstone Area*. National Academy Press, Washington, D.C.

Clapp, B., N. Walters, T. Thornburg, T. Hoyt, X. Yang, and D. W. Pascual, 2011. DNA vaccination of bison to brucellar antigens elicits elevated antibody and IFN-γ responses. *Journal of Wildlife Diseases* 47:501-510.

Cohen, N. D., G. K. Carter, and W. C. McMullan, 1992. Fistulous withers in horses: 24 cases (1984-1990). *Journal of the American Veterinary Medical Association* 201(1):121-124.

Cook, W. E., E. S. Williams, E. T. Thorne, T. J. Kreeger, G. Stout, K. Bardsley, H. Edwards, G. Schurig, L. A. Colby, F. Enright, P. H. Elzer, 2002. *Brucella abortus* strain RB51 vaccination in elk. I. Efficacy of reduced dosage. *Journal of Wildlife Diseases* 38(1):18-26.

Cook, W. E., E. S. Williams, and S. A. Dubay, 2004. Disappearance of bovine fetuses in northwestern Wyoming. *Wildlife Society Bulletin* 32(1): 254-259.

Corner, A. H. and R. Connell, 1958. Brucellosis in bison, elk, and moose in Elk Island National Park, Alberta, Canada. *Canadian Journal of Comparative Medicine and Veterinary Science* 22(1):9.

Craighead, J.J., G. Atwell, and B.W. O'Gara, 1972. Elk migration in and near Yellowstone National Park. Wildl. Monogr. 29. 48 pp.

Cross, P. C., E. K. Cole, A. P. Dobson, W. H. Edwards, K. L. Hamlin, G. Luikart, A. D. Middleton, B. M. Scurlock, and P. J. White, 2010. Probable causes of increasing brucellosis in free-ranging elk of the Greater Yellowstone Ecosystem. *Ecological Applications* 20(1):278-288.

Davis D. S., J. W. Templeton, T. A. Ficht, J. D. Huber, R. D. Angus, and L. G. Adams, 1991. *Brucella abortus* in bison.II. Evaluation of strain 19 vaccination of pregnant cows. *Journal of Wildlife Disease* 27(2):258–264.

Davis, D. S., W. J. Boeer, J. P. Mims, F. C. Heck, and L. G. Adams, 1979. *Brucella abortus* in coyotes. I. A serologic and bacteriologic survey in eastern Texas. *Journal of Wildlife Diseases* 15(3):367-372.

De Rautlin de la Roy, Y.M., B. Grignon, G. Grollier, M. Coindreau, & B. Becq-Giraudon, 1986. Rifampicin resistance in a strain of *Brucella melitensis* after treatment with doxycycline and rifampicin. *Journal of Antimicrobial Chemotherapy*, *18*(5), 648-649.

Dobson, A. and M. Meagher, 1996. The population dynamics of brucellosis in the Yellowstone National Park. *Ecology* 77:1026-1036.

Ebinger, M., P. Cross, R. Wallen, R. White, and P. J. Treanor, 2011. Simulating sterilization, vaccination, and test-and-remove as brucellosis control measures in bison. *Ecological Applications* 21:2944–2959.

Elzer, P. H., F. M. Enright, L. Colby, S. D. Hagius, J. V. Walker, M. B. Fatemi, J. D. Kopec, V. C. Beal Jr, and G. G. Schurig, 1998. Protection against infection and abortion induced by virulent challenge exposure after oral vaccination of cattle with Brucella abortus strain RB51. *American Journal of Veterinary Research* 59(12):1575-1578.

Enright, F. M., 1990. The pathogenesis and pathobiology of *Brucella* infection in domestic animals. *Animal brucellosis. CRC Press, Inc., Boca Raton, Fla*, 301-320.

Ferrari, M. J. and R. A. Garrott, 2002. Bison and elk: brucellosis seroprevalence on a shared winter range. *The Journal of Wildlife Management* 66:1246-1254.

Fenstermacher, R. and O. W. Olsen, 1942. Further studies of diseases affecting moose. *Cornell Veterinarian* 32:241-254.

Frey, R. K., P. R. Clarke, M. P. McCollum, P. Nol, K. R. Johnson, B. D. Thompson, J. M. Ramsey, N. J. Anderson, and J. C. Rhyan, 2013. Evaluation of Bison (Bison bison) Semen from Yellowstone National Park, Montana, USA, Bulls for Brucella abortus Shedding. *Journal of Wildlife Diseases* 49(3):714-717.

Gall, D. and K. Nielsen, 2004. Serological diagnosis of bovine brucellosis: a review of test performance and cost comparison. *Revue scientifique et technique (International Office of Epizootics)* 23(3):989.

Geremia, C., P. J. White, R. W. Wallen, F. G. R. Watson, J. J. Treanor, J. Borkowski, C. S. Potter, and R. L. Crabtree, 2011. Predicting bison migration out of Yellowstone National Park using Bayesian models. *PLoS One* 6:e16848.

Godfroid, J., B. Garin Bastuji, C. Saegerman, and J. M. Blasco Martínez, 2013. Brucellosis in terrestrial wildlife. *Rev. Sci. Tech* 32(1):27-42.

He, Y., 2012. Analyses of *Brucella* pathogenesis, host immunity, and vaccine targets using systems biology and bioinformatics. *Frontiers in Cellular and Infection Microbiol*ogy 2:1-17.

Higgins, J., T. Stuber, C. Quance, W. H. Edwards, R. V. Tiller, T. Linfield, J. Rhyan, A. Berte, and B. Harris, 2012. Molecular epidemiology of *Brucella abortus* isolates from cattle, elk, and bison in the United States: 1998 – 2011. *Applied and Environmental Microbiology*, doi: 10.1128/AEM.00045-12.

Hillier, F. S. and G. J. Lieberman, 2005. *Introduction to Operations Research 8E (Iae)*. Tata McGraw-Hill Education.

Hobbs, N.T., C, Geremia, J. Treanor, R. Wallen, P. J. White, M. B. Hooten, and J. C. Rhyan, 2013. State-space modeling to support adaptive management of Brucellosis in the Yellowstone bison population. *Unpublished*

Howard, R. A., 1971. *Dynamic Probabilistic Systems: Vol.: 1: Markov Models*. John Wiley and Sons, Incorporated.

Jellison, W. L., C. W. Fishel, and E. L. Cheatum, 1953. Brucellosis in a Moose, *Alces americanus*. *The Journal of Wildlife Management* 17(2):217-218.

Johnston, E. F., 1945. Fistulous Withers in a Horse. *Canadian Journal of Comparative Medicine and Veterinary Science* 9(1):14.

Jones, J. D., J. J. Treanor, R. L. Wallen, and P. J. White, 2010. Timing of parturition events in Yellowstone bison *Bison bison*: implications for bison conservation and brucellosis transmission risk to cattle. *Wildlife Biology* 16(3)333-339.

Ko, J. and G. A. Splitter, 2003. Molecular host-pathogen interaction in brucellosis: current understanding and future approaches to vaccine development for mice and humans. *Clinical Microbiology Reviews* 16(1):65-78.

Kauffman, M., B. Rashford, B. Scurlock, D. Peck, W. Cook, T. Cornish, W. H. Edwards, J. Logan, M. Ebinger, P. Cross, and B. A. Schumaker. A cost-benefit analysis of reducing *B. abortus seroprevalence* in southern GYA elk. Poster presented at The Wildlife Society Wyoming Chapter meeting, December 7, 2011, Jackson, WY.

Kilpatrick, A. M., Gillin, C. M. & Daszak, P., 2009. Wildlife–livestock conflict: the risk of pathogen transmission from bison to cattle outside Yellowstone National Park. *Journal of Applied Ecology* 46:476–485.

Kreeger, T. J., W. E. Cook, W. H. Edwards, P. H. Elzer, and S. C. Olsen, 2002. *Brucella abortus* strain RB51 vaccination in elk. II. Failure of high dosage to prevent abortion. *Journal of Wildlife Diseases* 38(1):27-31.

Lambert, G., C. A. Manthei and B. L. Deyoe, 1963. Studies on *Brucella abortus* infection in bulls. *American Journal of Veterinary Research* 24:1152.

Lambert, G., T. E. Amerault, C. A. Manthei, and E. R. Goode Jr, 1961. Further studies on the persistence of Brucella abortus infection in cattle. *Proceedings. United States Live Stock Sanitary Association* 1960:109-117.

Longini, I. M., M.G. Hudgens, M.E. Halloran, and K. Sagatelian, 1999. A Markov model for measuring vaccine efficacy for both susceptibility to infection and reduction in infectiousness for prophylactic HIV vaccines. *Statistics in medicine, 18*(1): 53-68.

Manthei, C. A., D. E. DeTray, and E. R. Goode, 1950. *Brucella* infection in bulls and the spread of brucellosis in cattle by artificial insemination. I. Intrauterine injection. *Journal of the American Veterinary Medical Association* 117:172-187.

Manthei, C. A., and R. W. Carter, 1950. Persistence of *Brucella abortus* infection in cattle. *American Journal of Veterinary Research* 11: 173-180.

McCorquodale, S. M. and R. F. DiGiacomo, 1985. The role of wild North American ungulates in the epidemiology of bovine brucellosis: a review. *Journal of Wildlife Diseases* 21(4):351-357.

Meagher, M. and M. E. Meyer, 1994. On the origin of brucellosis in bison of Yellowstone National Park: a review. *Conservation Biology* 8(3):645-653.

Mohler J. R., 1917. Abortion disease. In Annual reports of the Department of Agriculture Washington, D.C. U.S. Government Printing Office, Washington D.C., pages 105-106.

Montana Department of Livestock, *Designated Surveillance Area Economic Impact Statement*, 2011. Montana Department of Livestock, Economic Impact Statement.

Montana Fish, Wildlife & Parks, Feb. 2010. Final Environmental Assessment. Bison Translocation: Bison Quarantine Phase IV.

Morgan, W. J., 1969. Brucellosis in animals: diagnosis and control. *Proceedings of the Royal Society of Medicine* 62(10):1050

Murie, O., 1951. *The elk of North America*. The Stackpole Co., Harrisburg, Pa. and Wildlife Manag. Inst., Washington, D.C. Page 376.

National Park Service, USDA Animal and Plant Health Inspection Service, USDA Forest Service, Montana Department of Livestock, Montana Fish, Wildlife and Parks, 2005. A status review of adaptive management elements, 2000 to 2005.

Nicoletti, P., 1980. The epidemiology of bovine brucellosis. *Advances in Veterinary Science and Comparative Medicine* 24:69-98.

Oliveira, S. C., J. S. Harms, E. L. Rech, R. S. Rodarte, A. L. Bocca, A. M. Goes, and G. A. Splitter, 1998. The role of T cell subsets and cytokines in the regulation of intracellular bacterial infection. *Brazilian Journal of Medical and Biological Research* 31(1):77-84.

Olsen, S. C., 2000. Responses of adult cattle to vaccination with a reduced dose of *Brucella abortus* strain RB51. *Research in Veterinary Science* 69(2):135-140.

Olsen, S. C., A. E. Jensen, M. V. Palmer, and M.G. Stevens, 1998. Evaluation of serologicresponses, lymphocyte proliferative responses, and clearance from lymphatic organs after vaccination of bison with *Brucella abortus* strain RB51. *American Journal of Veterinary Research* 59:410-415.

Olsen, S. C. and C. S. Johnson, 2012. Efficacy of dart or booster vaccination with strain RB51 in protecting bison against experimental *Brucella abortus* challenge. *Clinical and Vaccine Immunology* 19(6):886-890.

Olsen, S. C., A. E. Jensen, W. C. Stoffregen, and M. V. Palmer, 2003. Efficacy of calfhood vaccination with *Brucella abortus* strain RB51 in protecting bison against brucellosis. *Research in Veterinary Science* 74:17-22.

Palmer, M. V., S. C. Olsen, M. J. Gilsdorf, L. M. Philo, P. R. Clarke, and N. F. Cheville, 1996. Abortion and placentitis in pregnant bison (*Bison bison*) induced by vaccine candidate, B*rucella abortus* strain RB51. *American Journal of Veterinary Research* 54:1604-1607.

Pappas, G. and P. Papadimitriou, 2007. Challenges in Brucella bacteraemia. *International Journal of Antimicrobial Agents* 30:29-31.

Pappas, G., P. Papadimitriou, N. Akritidis, L. Christou, and E. V. Tsianos, 2006. The new global map of human brucellosis. *The Lancet Infectious Diseases* 6(2):91-99.

Payne, J. M., 1959. The pathogenesis of experimental brucellosis in the pregnant cow. *The Journal of Pathology and Bacteriology* 78(2):447-463.

Peterson, M. J., W. E. Grant, and D. S. Davis, 1991. Simulation of host—parasite interactions within a resource management framework: impact of brucellosis on bison population dynamics. *Ecological Modelling* 54(3):299-320.

Plumb, G. E., P. J. White, M. B. Coughenour, and R. L. Wallen, 2009. Carrying capacity, migration, and dispersal in Yellowstone bison. *Biological Conservation* 142(11): 2377-2387.

Poester, F. P., B. S. P. Gonçalves, T. A. Paixão, R. L. Santos, S. C. Olsen, G. G. Schurig, and A. P. Lage, 2006. Efficacy of strain RB51 vaccine in heifers against experimental brucellosis. *Vaccine* 24:5327–5334.

Proffitt, K. M., J. L. Grigg, K. L. Hamlin, and R. A. Garrott, 2009 Contrasting effects of wolves and human hunters on elk behavioral responses to predation risk. *The Journal of Wildlife Management* 73(3):345-356.

Proffitt, K. M., P. J. White, and R. A. Garrott, 2010. Spatio-temporal overlap between Yellowstone bison and elk – implications for wolf restoration and other factors for brucellosis transmission risk. *Journal of Applied Ecology* 47:281-289.

Proffitt, K. M., J. A. Gude, K. L. Hamlin, R. A. Garrott, J. A. Cunningham, and J. L. Grigg, 2011. Elk distribution and spatial overlap with livestock during the brucellosis transmission risk period. *Journal of Applied Ecology* 48(2), 471-478.

Racloz, V., E. Schelling, N. Chitnis, F. Roth, and J. Zinsstag, 2013. Persistence of brucellosis in pastoral systems. *Revue scientifique et technique (International Office of Epizootics)* 32(1):61-70.

Ragan, V. E., 2002. The animal and plant health inspection service (APHIS) brucellosis eradication program in the United States. *Veterinary Microbiology* 90(1):11-18.

Rankin, J. E., 1965. B*rucella abortus* in bulls: a study of twelve naturally-infected cases. *The Veterinary Record* 77:132.

Rhyan, J. C., 2013a. Pathogenesis and pathobiology of brucellosis in wildlife. *Revue scientifique et technique (International Office of Epizootics)* 32(1)127-136.

Rhyan, J. C., K. Aune, D. R. Ewalt, J. Marquardt, J. W. Mertins, J. B. Payeur, D. A. Saari, P. Schladweiler, E. J. Sheehan, and D. Worley, 1997. Survey of free-ranging elk from Wyoming and Montana for selected pathogens. *Journal of Wildlife Diseases* 33(2):290-298.

Rhyan, J. C., K. Aune, T. Roffe, D. Ewalt, S. Hennager, T. Gidlewski, S. Olsen, and R. Clarke, 2009. Pathogenesis and epidemiology of brucellosis in Yellowstone bison: serologic and culture results from adult females and their progeny. *Journal of Wildlife Diseases* 45(3):729-739.

Rhyan, J. C., P. Nol, C. Quance, A. Gertonson, J. Belfrage, L. Harris, and S. Robbe-Austerman, 2013b. Transmission of brucellosis from elk to cattle and bison, Greater Yellowstone area, USA, 2002–2012. *Emerging Infectious Diseases* 19(12):1992.

Roberts, T. W., D. E. Peck, and J. P. Ritten, 2012. Cattle producers' economic incentives for preventing bovine brucellosis under uncertainty. *Preventive Veterinary Medicine* 107(3-4):187-203.

Robison, C. D., D. S. Davis, J. W. Templeton, M. Westhusin, W. B. Foxworth, M. J. Gilsdorf, and L.G Adams, 1998. Conservation of germ plasm from bison infected with *Brucella abortus*. *Journal of Wildlife Diseases* 34(3):582-589.

Roth, F., J. Zinsstag, D. Orkhon, G. Chimed-Ochir, G. Hutton, O. Cosivi, G. Carrin, and J. Otte, 2003. Human health benefits from livestock vaccination for brucellosis: case study. *Bulletin of the World Health Organization* 81(12):867-876.

Salmakov, K. M., A. M. Fomin, E. M. Plotnikova, G. M. Safina, G. M. Galimova, A. V. Salmakova, A. V. Ivanov, A. N. Panin, O. D. Sklyarov, K. V. Shumilov, A. I. Klimanov, 2010. Comparative study of the immunobiological properties of live brucellosis vaccines. *Vaccine* 28:F35-F40.

Schnurrenberger, P. R., R. R. Brown, E. P. Hill, C. M. Scanlan, J. A. Altiere, and J. T. Wykoff, 1985. *Brucella abortus* in wildlife on selected cattle farms in Alabama. *Journal of wildlife diseases* 21(2):132-136.

Schumaker, B. A., 2010. Detection and transmission dynamics of *Brucella abortus* in the Greater Yellowstone area. Ph.D. thesis, University of California, Davis.

Schumaker, B. A., 2013. Risks of *Brucella abortus* spillover in the Greater Yellowstone area. *Revue scientifique et technique (International Office of Epizootics)* 32(1):71-77.

Scurlock, B. M. and W. H. Edwards, 2010. Status of brucellosis in free-ranging elk and bison in Wyoming. *Journal of Wildlife Diseases* 46(2):442-449.

Seleem, M. N., S. M. Boyle, and N. Sriranganathan, 2010. Brucellosis: a re-emerging zoonosis. *Veterinary microbiology* 140(3):392-398.

Smith, T., 1919. A characteristic localization of *Bacillus abortus* in the bovine fetal membranes. *The Journal of Experimental Medicine* 29(5):451-456.

Stevens, M. G., S. C. Olsen, and N. F. Cheville, 1995. Comparative analysis of immune responses in cattle vaccinated with *Brucella abortus* strain 19 or strain RB51. *Veterinary immunology and immunopathology* 44(3):223-235.

Tessaro, S. V., 1986. The existing and potential importance of brucellosis and tuberculosis in Canadian wildlife: A review. *The Canadian Veterinary Journal* 27(3):119

Thomsen, A., 1943. Does The bull spread infectious abortion in cattle? Experimental studies from 1936 to 1942. *Journal of Comparative Pathology and Therapeutics* 53:199-211.

Treanor, J. J., 2013. Integrating ecology with management to control wildlife brucellosis. *Revue scientifique et technique (International Office of Epizootics)* 32(1):239-247.

Treanor, J. J., C. Geremia, P. H. Crowley, J. J. Cox, P. J. White, R. L. Wallen, and D. W. Blanton, 2011. Estimating probabilities of active brucellosis infection in Yellowstone bison through quantitative serology and tissue culture. *Journal of Applied Ecology* 48:1324-1332.

Treanor, J. J., J. S. Johnson, R. L. Wallen, S. Cilles, P. H. Crowley, J. J. Cox, D. S. Maehr, P. J. White, G. E. Plumb, 2010. Vaccination strategies for managing brucellosis in Yellowstone bison. *Vaccine* 28S:F64-F72.

Uhrig, S. R., P. Nol, M. McCollum, M. Salman, and J. C. Rhyan, 2013. Evaluation of transmission of *Brucella Abortus* strain 19 in bison by intravaginal, intrauterine, and intraconjunctival inoculation. *Journal of Wildlife Diseases* 49(3):522-526.

U. S. Department of Agriculture and Animal and Plant Health Inspection Service, 2010. Brucellosis Class Free States and Certified Brucellosis-Free Herds; Revisions to Testing and Certification Requirements. Docket No. APHIS-2009-0083, Federal Register, **75**(247):81090-81096

U. S. Department of Agriculture and Animal and Plant Health Inspection Service, 2013. *Bovine Tuberculosis and Brucellosis Surveillance Results*. Monthly Reports, Federal Fiscal Year (FY) 2014. October 1–31.

U.S. Department of the Interior, National Park Service, U.S. Department of Agriculture, Forest Service, Animal and Plant Health Inspection Service, and the State of Montana, Department of Fish, Wildlife, and Parks, and Department of Livestock, 2008. *Adaptive adjustments to the interagency bison management plan*. National Park Service, Yellowstone National Park, Wyoming.

U.S. Government Accountability Office, 2008. Interagency Plan and Agencies' Management need improvement to better address Bison – cattle brucellosis controversy. GAO-08-291

Wanke, M.M., 2004. Canine brucellosis. *Animal Reproduction Science* 82:195-207.

White, P. J., J. J. Treanor, C. Geremia, R. L. Wallen, D. W. Blanton, and D. E. Hallac, 2013. Bovine brucellosis in wildlife: using adaptive management to improve understanding, technology and suppression. *Revue scientifique et technique (International Office of Epizootics)* 32(1):263-270.

White, P. J., R. L. Wallen, C. Geremia, J. J. Treanor, and D. W. Blanton, 2011. Management of Yellowstone bison and brucellosis transmission risk – expectations and realizations. *Biological Conservation* 144:1322–1334.

Wilson, B.A., 2011. Regional economic impacts of bovine brucellosis under new federal regulations. Thesis, Department of Agricultural and Applied Economics, Laramie, Wyoming, USA.

Wise, R.I., 1980. Brucellosis in the United States. Past, present, and future. *The Journal of the American Medical Association* 244: 2318–22

World Health Organization, 2013. DNA Vaccines. Retrieved from: http://www.who.int/biologicals/areas/vaccines/dna/en/

World Health Organization (WHO), Food and Agriculture Organization of the United Nations, and World Organisation for Animal Health, 2006. Brucellosis in humans and animals. WHO Press, Geneva, Switzerland.

Wright, A. E., 1937. Progress in the Federal-State Bang's Disease Program. *Journal of the American Veterinary Medical Association* 90:268-273.

Yang, X., M. Hudson, N. Walters, R. F. Bargatze, and D. W. Pascual, 2005. Selection of protective epitopes for Brucella melitensis by DNA vaccination. *Infection and Immunity* 73(11):7297-7303.

Yaesoubi, R., and T. Cohen, 2011. Generalized Markov models of infectious disease spread: A novel framework for developing dynamic health policies. *European Journal of Operational Research*, *215*(3), 679-687.Young, E. J, 1995. An overview of human brucellosis. *Clinical infectious diseases,* 21(2), 283-289.

Young, E. J, 1995. An overview of human brucellosis. *Clinical infectious diseases*, **21**(2), 283-289.

Young, E. J., and M. J. Corbel (Eds.), 1989. *Brucellosis: clinical and laboratory aspects*. CRC Press, Baca Raton, Florida, USA, pages 47-48.

Xavier, M. N., T. A. Paixão, A. B. Hartigh, R. M. Tsolis, and R. L. Santos, 2010. Pathogenesis of Brucella spp. *Open Veterinary Science Journal* 4(1):109-118.

Xavier, M. N., T. A. Paixão, F. P. Poester, A. P. Lage, and R. L. Santos, 2009. Pathological, Immunohistochemical and Bacteriological Study of Tissues and Milk of Cows and Fetuses Experimentally Infected with *Brucella abortus*. *Journal of Comparative Pathology* 140(2):149-157.

Xie, F. and R. D. Horan, 2009. Disease and behavioral dynamics for brucellosis control in elk and cattle in the Greater Yellowstone Area. *Journal of Agricultural and Resource Economics* 34(1):11-33.

Zipkin, E. F., C. S. Jennelle, and E. G. Cooch, 2010. A primer on the application of Markov chains to the study of wildlife disease dynamics. *Methods in Ecology and Evolution*, 1(2): 192-198.

Personnel:

Prof. Myles Watts and Prof. Randal Rucker—Montana State University, Department of Agricultural Economics and Economics

Both Prof. Watts and Prof. Rucker will be the co-Principal Investigators on this project. Both are academics who have a long history of working on issues related to the economics of agriculture and to the management of natural resources in Montana and throughout the United States. Prof. Watts and Prof. Rucker have published work, both with each other and with others, on the cattle industry. Prof. Watts has substantial experience in finance and insurance—both public and private. He was the lead actuary on the development of domestic livestock disease insurance that covered several diseases, including brucellosis.

Prof. Joseph Atwood—Montana State University, Department of Agricultural Economics and Economics

Prof. Atwood is one of the pre-eminent experts in programming in R, which is the platform that is likely to be the most appropriate for the modeling to be undertaken in this project. He has extensive experience in mathematical modelling of risk and unlikely events.

Prof. Timothy Fitzgerald—Montana State University, Department of Agricultural Economics and Economics

Prof. Fitzgerald has experience and expertise in working with a broad range of dynamic and stochastic models in contexts that are expected to be highly relevant to the undertakings in this project.

Prof. David Pascual

Prof. Pascual is a professor of immunology in the College of Veterinary Medicine at the University of Florida. One of his major research efforts is focused on subunit vaccines for *Brucella* pathogens. He is recognized as a leading expert on the Yellowstone bison brucellosis issue.

Jay Winship

Dr. Winship has substantial private sector experience in the development of drugs and vaccines. Early in his career, he was a practicing medical doctor. Later, he was involved in the development and commercialization of a number of drugs and vaccines. Dr. Winship has had a long term interest in brucellosis issues.

Amanda Vogstad—Montana State University

Ms. Vogstad is a graduate student with a background in veterinary epidemiology. She has proven to be invaluable in the early stages of this project.

Curriculum Vitae

December 2013

MYLES J. WATTS

Agricultural Economics & Economics Department
Montana State University
Bozeman, MT 59717-2920
(406) 994-3704

2801 Texas Way
Bozeman, MT 59715
(406) 586-1481

EDUCATION:

- **Ph.D., Agricultural Economics**, University of Nebraska, Lincoln, July 1978
- **M.S., Applied Economics**, Montana State University, Bozeman, December 1975
- **B.S., Agricultural Business**, Montana State University, Bozeman, June 1973

EMPLOYMENT HISTORY:

- Professor of Agricultural Economics, Department of Agricultural Economics and Economics, Montana State University, Bozeman (July 1990–present)
- Department Head, Department of Agricultural Economics and Economics, Montana State University, Bozeman (January 1985–October 1991; September 1995-November 2002; July 2006–June 2009)
- Associate Professor of Agricultural Economics, Department of Agricultural Economics and Economics, Montana State University, Bozeman (July 1984–July 1990)
- Assistant Professor of Agricultural Economics, Department of Agricultural Economics and Economics, Montana State University, Bozeman (July 1978–July 1984)
- Instructor, Department of Agricultural Economics, University of Nebraska, Lincoln (September 1975–January 1976; September 1976–January 1977; September 1977–July 1978)
- Graduate Research Assistant, Department of Agricultural Economics, University of Nebraska, Lincoln (February 1976–August 1976; February 1977–August 1977)
- Rancher, Miles City, Montana — Involved in a family ranch partnership (June 1973–August 1975)
- Teaching Assistant, Department of Agricultural Economics and Economics, Montana State University, Bozeman (September 1972–June 1973)

PROFESSIONAL SOCIETIES AND RECOGNITIONS:

- Outstanding Graduate Student, Department of Agricultural Economics, University of Nebraska (1977)
- National Science Foundation Fellowship to pursue master's thesis research (September 1973–June 1975)
- Gamma Sigma Delta
- Omicron Delta Epsilon
- American Agricultural Economics Association
- Western Agricultural Economics Association
- American Economic Association
- Editor, *Journal of Agricultural and Resource Economics*, 1991–1995.
- Outstanding Journal Article Award, American Agricultural Economics Association, 1996 (Honorable mention with J.T. LaFrance)
- Outstanding Masters Thesis Award (with J. Chovosta, Graduate Student), Western Agricultural Economics Association, 1998 (Honorable Mention with R. Rucker)
- Distinguished Scholar, Western Agricultural Economics Association, 2006
- Co-Editor, *Journal of Agricultural and Resource Economics*, 2009-2012
- Farmer Mac Board of Directors. Nominated by Senator Mitch McConnell, appointed by President Barack Obama, confirmed by United States Senate, 2010-current
- Distinguished Scholar Award, College of Agriculture, Montana State University (First Recipient) 2013

MAJOR RESEARCH EFFORTS:

- Risk management with primary interest in risk mitigation mechanisms. Involved in over 100 insurance efforts, mostly with crop and livestock insurance including insurance. Actuarial efforts with various data deficiencies including limited data.
- Measurement and implementation of safeness and soundness regulation of financial institutions both domestically and internationally.
- Use of public lands for grazing of domestic livestock.
- Tax and other policy influences on water quality.

PUBLICATIONS:
Refereed Journal Articles and Book:

- [With J.A. Atwood]. "Risk Premiums in Interest Rates." In process.
- [With J.L. Steele, J.P. Shimshak, and J.T. LaFrance]. "The Public Resource Management Game." *Journal of Economics, Dynamics, and Control.* Submitted paper.
- [With J.A. Atwood, B. Beattie]. "Environmental Policy Implications When Whole-farm irrigation Water is Fixed." *Australian Journal of Agriculture and Resource Economics.* Revise and resubmit.
- [With A. Bekkerman and V.H. Smith]. (2012) "The SURE Program and Incentives for Crop Insurance. Participation." *Agricultural Finance Review* Vol. 72, no 3: 381-401.
- [With V. Smith]. "New Standing Disaster Program: An Invitation to Moral Hazard." *Applied Economic Perspectives and Policies*, Vol. 32, no. 1 (Spring 2010): 154-169.
- [With B. Beattie and R. Taylor]. "The Economics of Production." Krieger Publishing Company: FL, 2009.
- [With J. Vanek and G. Brester]. "Genetic Selection in the Beef Industry: Are Feeder Cattle Producers Compensated for Improving Carcass Quality?" *Journal of Agricultural and Resource Economics* Vol. 3, no. 3 (Dec. 2008): 349-363.
- [With J.A. Atwood, and S. Shaik]. "Are Crop Yields Normally Distributed?: A Reexamination." *American Journal of Agricultural Economics* Vol. 85, no. 4 (Nov. 2003): 888-901.
- [With B.R. Beattie, and M.T. Holt]. "On the Function Coefficient, Eulers Theorem, and Homogeneity in Production Theory." *Review of Agricultural Economics* Vol. 24, no. 1 (Spring/Summer 2002): 240-249.
- [With J.A. Atwood and, S. Shaik]. "Can Normality of Yields Be Assumed for Crop Insurance?" *Canadian Journal of Agricultural Economics* Vol. 50, no. 2 (July 2002): 171-184.
- [With J. Chvosta, and R.R. Rucker]. "Transaction Costs and Cattle Marketing: The Information Content of Seller-Provided Data at Bull Auctions." *American Journal of Agricultural Economics* Vol. 83, no. 2 (May 2001): 286-301.
- [With D. Buschena]. "(How) Do Prerequisites Matter? Analysis of Intermediate Microeconomics and Agricultural Economics Grades." *Review of Agricultural Economics* Vol. 23, no. 1 (Spring/Summer 2001): 203-213.
- [With L. Egan]. "Some Costs of Incomplete Property Rights with Regard to Grazing Permits." *Land Economics* Vol. 74, no. 2 (May 1998): 171-185.

- [With G. Haynes]. "Finance Companies and Small Business Borrowers: Does the Pawn Shop Label Fit?" *Entrepreneurship and Small Business Finance* Vol. 5, no. 1 (February 1996).
- [With J.A. Atwood and A. E. Baquet]. "An Examination of the Effects of Price Supports and Federal Crop Insurance Upon the Economic Growth, Capital Structure, and Financial Survival of Wheat Growers in the Northern High Plains." *American Journal of Agricultural Economics* Vol. 78, no. 1 (February 1996): 212-224.
- [With C.L. Wambolt]. "Long Term Recovery of Wyoming Big Sagebrush." *Journal of Environmental Management* Vol. 46, no. 1 (February 1996): 95-102.
- [With J.T. LaFrance] "Public Grazing in the West and 'Rangeland Reform '94.'" *American Journal of Agricultural Economics* Vol. 77, no. 3 (August 1995): 447-461.
- [With J.T. LaFrance]. "Guidelines for Western Journal of Agricultural Economics Authors." *Western Journal of Agricultural Economics* Vol. 16, no. 2 (December 1991), ("Soft" Review).
- [With C. Wambolt]. "Economic Evaluation of Wyoming Big Sagebrush (*Artemisia tridentata*) Control Methods." *Weed Technology* Vol. 3, no. 4 (October/December 1989).
- [With R.N. Johnson]. "Contractual Stipulations, Resource Use and Interest Groups: Implications from Federal Grazing Contracts." *Journal of Environmental Economics and Management* Vol. 16, no. 1 (1989): 87–96.
- [With J.A. Atwood, G.A. Helmers, and L.J. Held]. "Incorporating Safety-First Constraints in Linear Programming Production Models." *Western Journal of Agricultural Economics* Vol. 13, no. 1 (July 1988): 29–36.
- [With J.A. Atwood and G.A. Helmers]. "Chance-Constrained Financing as a Response to Financial Risk." *American Journal of Agricultural Economics* Vol. 70, no. 1 (February 1988): 79–89.
- [With B.R. Beattie]. "The Proper Preeminent Role of Central Disciplines and Learned Societies in Setting the Agenda at Land Grant Universities." *Western Journal of Agricultural Economics* Vol. 12, no. 2 (December 1987): 95–103.
- [With J.A. Atwood, L.J. Held, and G.A. Helmers]. "Performance of Risk Income Models Outside of the Original Data." *Southern Journal of Agricultural Economics* Vol. 18, no. 2 (December 1986): 113-123.
- [With J.T. LaFrance]. "The Value of Protein in Feed Barley for Beef, Dairy and Swine Feeding." *Western Journal of Agricultural Economics* Vol. 11, no. 1 (July 1986): 76-81.
- [With G.A. Helmers and J.A. Atwood]. "Relevancy of Cash Flow in Firm Financial Management." *Agribusiness: An International Journal* (Winter 1985).
- [With G.A. Helmers, L.J. Held, and J.A. Atwood]. "Deviation Constrained Programming: The Impact on Risk–Income Frontiers." *North Central Journal of Agricultural Economics* Vol. 6, no. 2 (July 1984): 142-150.
- [With L.J. Held and G.A. Helmers]. "A Comparison of Target MOTAD to MOTAD." *Canadian Journal of Agricultural Economics* Vol. 32 (March 1984): 175-186.
- [With L.J. Held]. "Comparing Acceleration of New ACRS Versus Prior Law Double Declining Balance Depreciation: A Present Value Approach." *North Central Journal of Agricultural Economics* Vol. 5, no. 2 (July 1983): 11-17.

- "Machinery Repair Functions and Depreciation." *North Central Journal of Agricultural Economics* Vol. 4, no. 1 (January 1982): 69-72.

- [With G.A. Helmers]. "Machinery Cost and Inflation." *Western Journal of Agricultural Economics* Vol. 6, no. 2 (December 1981): 129-145.

- [With G.A. Helmers]. "Inflation and Machinery Cost Budgeting." *Southern Journal of Agricultural Economics* Vol. 11, no. 2 (December 1979): 83-88.

Presented Papers:

- [With A. Kellom, J. Peterson, J. Vanek, and M. Harbo]. "The Effects of Age and Source Verification of Calves on Value Received on Superior Livestock Video Auctions." Proceedings of Western Section, American Society of Animal Science, Vol. 59, 2008: 137-139.

- "Public Land Grazing Contracts." Presented at WAEA, 2006.

- "Participation in Crop Insurance." Presented at AAEA meeting, 2000.

- [With L. Egan]. "Some Costs of Incomplete Property Rights with Regard to Federal Grazing Permits." Presented at the annual meeting of the AAEA, 1997.

- [With J. Chovosta and R. Rucker]. "The Information Content of Seller-Provided Data in Cattle Auctions." Presented at the annual meeting of the AAEA, 1997.

- "Issues in Developing Revenue Insurance Products." Presented at the annual meeting of the AAEA, San Antonio, Texas, July 1996.

- [With J.T. LaFrance]. "Privatizing Land Use Rights on Public Lands." Presented at the annual meeting of the AAEA, 1996.

- [With J.A. Atwood, and V.H. Smith]. "Lemons, List Prices, and Other Problems with Measuring Economic Depreciation Rates for Agricultural Machinery." Presented at the annual meeting of the WAEA, Portland, Oregon, July 1991. [Abstract published in the *Western Journal of Agricultural Economics*, December 1991.]

- [With J. Goroski, V.H. Smith, and J.A. Atwood]. "Economic Depreciation and Tax Policy: The Case of Combine Harvesters." Presented at the annual meeting of the AAEA, Vancouver, B.C., Canada, August 1990. [Abstract published in the *American Journal of Agricultural Economics*, December 1990.]

- [With J.A. Atwood]. "Safety-First Programming: A Zero-One Approach." Paper presented at the annual meeting of the AAEA, Baton Rouge, Louisiana, August 1989. [Abstract published in the *American Journal of Agricultural Economics*, December 1989.]

- "Comments on Dynamic Programming." Invited paper presented at the annual meeting of the WAEA, Honolulu, Hawaii, July 1988.

- [With G.A. Helmers, J.A. Atwood, and L.J. Held]. "Financial Performance of Risk-Income Modules." Paper presented at the annual meeting of the WAEA, July 1987. [Abstract published in the *Western Journal of Agricultural Economics*, December 1987.]

- [With L.J. Held, G.A. Helmers, and J.A. Atwood]. "Effect of Machinery Cost Economies on Diversified Risk-Efficient Plans." Paper presented at the annual meeting of the WAEA, July 1987. [Abstract published in the *Western Journal of Agricultural Economics*, December 1987.]

- [With L.J. Held, G.A. Helmers, and J.A. Atwood]. "Impact of Business Versus Financial Risk on Risk Income Choices." Paper presented at the annual meeting of the AAEA. [Abstract published in the *American Journal of Agricultural Economics*, December 1986.]

- [With J.A. Atwood and G.A. Helmers]. "Reduction of Second Degree Stochastic Efficient Sets Using Safety-First Type Constraints." Paper presented at the annual meeting of the WAEA, July 1985. [Abstract published in the *Western Journal of Agricultural Economics*, December 1985.]

- [With M.D. Copeland]. "Income Taxes and Distribution of Asset Ownership." Paper presented at the annual meeting of the WEA, 1985.

- [With B.E. Bravo-Ureta]. "Tax Policy and Invariant Asset Valuations Under Inflation." Paper presented at the annual meeting of the AAEA, 1984.

- [With G.A. Helmers, and L.J. Held]. "Farm Firm Programming Models Using Risk and Annual Income Targets." Paper presented at the annual meeting of the Western Agricultural Economics Association, 1983.

- [With G.A. Helmers, and L.J. Held]. "Estimating the Impact of Safety-First Risk Constraints on Risk-Income Frontiers. " Paper presented at the annual meeting of the AAEA, 1982. [Abstract published in the *American Journal of Agricultural Economics*, December 1982.]

- [With G.A. Helmers]. "The Effect of Inflation and Income Tax on Machinery Cost and Optimum Replacement." Paper presented at the winter meeting of the American Society of Agricultural Engineers, 1981.

- [With G.A. Helmers]. "Tax and Inflation Adjustments for Machinery Cost Models." Paper presented at the annual meeting of the AAEA, 1978. [Abstract published in the *American Journal of Agricultural Economics*, December 1978.]

- [With G.A. Helmers]. "Land Appreciation Rates and Economic Justification of Land Values." Paper presented at the annual meeting of the AAEA, 1977. [Abstract published in the *American Journal of Agricultural Economics*, December 1977.]

Other Publications and Papers:

- [G. Haynes and D. Young]. "Project 2030." Department of Agricultural Economics and Economics, Montana State University, 2013

- [G. Brester and G Reusche]. "Introduction to Agricultural Insurance and Risk Management." International Finance Corporation, World Bank Group, 2013.

- [G. Brester and G. Reusche]. "Acturial Basics." International Finance Corporation, World Bank Group, 2013.

- [G. Brester and G. Reusche]. "Data and Information Management." International Finance Corporation, World Bank Group, 2013.

- [G. Haynes and D. Young]. "Fiscal Impacts of an Aging Population in Montana." *Montana Business Quarterly* (Autumn 2008).

- [With D. Young]. "Understanding School Finances." *Montana Policy Review* (Summer 2005).

- [With D. Young]. "Montana School Quality." *Montana Business Quarterly* (Summer 2005).

- [With J. Atwood]. "Analysis of Difference Between IP and MPCI Rates (Cotton Review)." Staff Paper Number 2001-01, Department of Agricultural Economics and Economics, Montana State University, Bozeman.

- [With J. Atwood]. "Examination of Adverse Selection in Crop Insurance." Staff Paper Number 2001-02, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With J. Atwood and S. Shaik]. "Assessment of Implementability of Income Protection," Department of Agricultural Economics and Economics, Montana State University, Bozeman, December 2001.
- "Agricultural Outlook." *Montana Business Quarterly* (Winter 2000).
- [With B. Sowell]. "Range/Pasture Crop Insurance: Stage 1 Report." Staff Paper Number 2000-1, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With C. Prince]. "Optional Units." Staff Paper Number 2000-3, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With I. Anderson]. "The Effects of Adverse Selection and Effective Coverage Levels of Crop Insurance Participation." Staff Paper Number 2000-4, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With J. Atwood, and S. Shaik]. "Low Risk Farmer." Staff Paper Number 2000-5, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With J. Atwood]. "Rating Avocado Revenue Insurance: An Overview." Staff Paper Number 2000-6, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With J. Atwood, J. Driscoll, and V. Smith]. "Federal Crop Insurance Programs, History, Practice and Issues". Staff Paper Number 1999a- 4, 5, 6, Department of Agricultural Economics and Economics, Montana State University.
- "Agricultural Outlook." *Montana Business Quarterly* (Winter 1999)
- [With D. Buschena]. "Land Use in the Northern Great Plains: What Does the Future Hold?" Chapter 9 in 2000 WTO Negotiations (Young, Johnson and Smith, eds.) 1999.
- [With J.T. LaFrance]. Chapter 16: "Contract Design for Public Lands Grazing." Designing Institutions for Environmental and Resources Management. Eds. E.T. Loehman and D.M. Kilgour. Edward Elgar Publishers, NY, March 1998.
- [With J. Atwood, and A. Baquet]. "Income Protection," Staff Paper Number 1997-9, Department of Agricultural Economics and Economics, Montana State University, Bozeman.
- [With H. Fretwell]. "Montana's Agriculture and Other Basic Industries." Published by Montana State University, Bozeman, Montana, October 1996.
- [With J.T. LaFrance]. "Cows, Cowboys, and Controversy: The Grazing Fee Issue." Book chapter in *Multiple Conflicts over Multiple Uses* (1994).
- [With J.A. Atwood]. "Bootstrapping Discrete Markovian Transition Probabilities with Complete and Reduced Sets of State Variables." Published in *Quantifying Long Run Agricultural Risks and Evaluating Farmer Responses to Risk. Proceedings of a seminar sponsored by Southern Regional Project S-232*. Department of Resource Economics and Policy, University of Maine, Orono, Maine, June 1993.
- "Agricultural Outlook." *Montana Business Quarterly* (Winter 1993).

- [With P. Seibrasse]. "Tax Reform or Revision? Montana Must Decide." *Special Bulletin of the Montana Extension Service*, May 1993.
- [With S. Zhihua]. "State Budgets and Montana Experiment Station Funding." Staff Paper Number 1993-3, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1993.
- [With P. Seibrasse]. "Montana Taxes." Staff Paper Number 1993-4, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1993.
- [With J.A. Atwood, B.E. Bravo-Ureta, G.A. Helmers, and V.H. Smith]. "Implications of Tax Policy for Farm Structure." Book chapter in *Farm Structure*, Iowa State Press, 1993.
- "Agricultural Outlook." *Montana Business Quarterly* (Winter 1992).
- "Report of the Agricultural Land Advisory Committee." Prepared for the Montana Department of Revenue, Helena, 1992.
- [With G.A. Helmers]. "Measurement Issues Relating to Economic Analysis." Chapter 3 in *Costs and Returns for Agricultural Commodities - Advances in Concepts and Measurements* (Ahearn and Usasavada, eds.), Westview Press, 1992.
- "An Economic Analysis of Wyoming Big Sagebrush Control." *Montana AgResearch* (Summer/Fall 1990).
- "Extension and Non-Extension Funded Faculty Relationships." Paper prepared for the annual meetings of the Western Agricultural Economics Council, Tucson, Arizona, 5–6 January 1989.
- [With J.B. Johnson, A.E. Baquet, and D. Griffith]. "Setting Maximum Acceptable Rental Rates for Counties According to Criteria Specified in CRP-92." Staff Paper Number 88-15, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1988.
- [With J.B. Johnson and A.E. Baquet]. "Fallow Economics." *Crops and Soils Magazine* (1987), American Society of Agronomy.
- "Analyzing Financial Health and Liquidation." Staff Paper Number 86-5, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1986.
- [With J.B. Johnson, A.E. Baquet, and C. Miller]. "The Economics of Alternative Tillage Methods and Cropping Systems: Major Land Resource Areas 53A and 58A in Eastern Montana." Bulletin 1351, Montana Cooperative Extension Service, Montana State University, Bozeman, September 1986.
- [With J.B. Johnson]. "The Relationship of Inflation to Agricultural Income, Asset Values and Firm Financial Analysis." Staff Paper Number 85-6, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1985. [Reprinted in the 1985 NCR-117 Proceedings.]
- [With J.A. Atwood and G.A. Helmers]. "Safety-First Models Based on Sample Statistics." In: *Risk Analysis for Agricultural Production Firms: Concepts, Information Requirements, and Policy Issues*. Department of Agricultural Economics, Michigan State University, 1985.
- [With G.A. Helmers]. "Developing Inflation-Free Cost and Returns for Risk and Other Economic Analysis." Paper presented at the annual meeting of the GPC-10 Regional Committee and published in proceedings, 1985.
- [With C.A. Roheim and C.R. Taylor]. "Economic Feasibility of Small Wind Energy Generator Systems." Staff Paper Number 85-1, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1985.

- [With J.T. LaFrance]. "The Value of Feed Barley in Beef, Dairy, and Swine Feeding." Staff Paper Number 85-5, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1985.
- [With L.D. Bender and J.B. Johnson]. "Economic Incentives for the Conversion of Rangeland to Cropland." Bulletin 1302, Montana Cooperative Extension Service, Montana State University, Bozeman, November 1983.
- [With G.I. Goodman]. "IRA's: More Than a Retirement Account." *Big Sky Economics* (December 1982), Montana Cooperative Extension Service.
- [With R.M. Schultz and D.J. Dunn]. "Debt Servicing Capacity and Inflation." *Big Sky Economics* (September 1982), Montana Cooperative Extension Service.
- [With G.I. Goodman, D.J. Dunn, and M.S. Stauber]. "How Often Should Alfalfa Stands Be Replaced?" *Big Sky Economics* (June 1982), Montana Cooperative Extension Service.
- [With R.W. Schultz]. "Land as an Investment." Staff Paper Number 82-5, Department of Agricultural Economics and Economics, Montana State University, Bozeman, June 1982.
- [With D.J. Dunn]. "Machinery Acquisition and Tax Management." Staff Paper Number 82-4, Department of Agricultural Economics and Economics, Montana State University, Bozeman, May 1982.
- [With L.J. Held and G.A. Helmers]. "Deriving a More Efficient Risk-Income Frontier: The MONID Approach." Paper presented at the annual meeting of the GPC-10 Regional Committee, May 1982 (and published in proceedings, 1982).
- [With C.A. Roheim]. "Management Under Financial Crisis." Staff Paper Number 82-1, Department of Agricultural Economics and Economics, Montana State University, Bozeman, January 1982.
- [With G.A. Helmers]. "Machinery Cost and Inflation." In: *Developing and Using Farm and Ranch Cost of Production and Return Data*. Great Plains Agricultural Council Publication No. 95, January 1981.
- [With R.J. Downer]. *Public and Private Grazing Resources in Montana with Emphasis on Forest Service Administered Grazing*. Montana Agricultural Experiment Station Research Report No. 164, November 1980.
- [With G.A. Helmers]. "Machinery Cost and Income Taxes." Staff Paper Number 80-12, Department of Agricultural Economics and Economics, Montana State University, Bozeman, 1980.
- "Impacts of Tax Policy on Machinery Investment." Invited paper presented at the meeting of the Great Plains Resource Economics Committee, 5 June 1979.
- "Growth, Expansion, Profitability, and Survival in Agriculture." Paper presented at the Montana Agricultural Loan Officers Annual Conference, 1979.
- [With G.A. Helmers]. "Machinery Depreciation." *Successful Farming* (February 1978).
- [With G.A. Helmers]. "Methodological Discussion and Illustration of Capital Budgeting Used to Estimate Annual Machinery Costs." Staff Paper, Department of Agricultural Economics, University of Nebraska, Lincoln, September 1977.
- "Labor Value and Farm Machinery Size." *Cornhusker Economics* (June 1977), Cooperative Extension Service, University of Nebraska, Lincoln.

- "Tax Exemption or Tax Credit?" *Cornhusker Economics* (April 1977), Cooperative Extension Service, University of Nebraska, Lincoln.

- [With G.A. Helmers]. "Machinery Trading and Tax Alternatives." *Farm, Ranch, and Home Quarterly* (Winter 1977), University of Nebraska, Lincoln.

- "Estimated Cost of Spoil Bank Reclamation Alternatives" (Master's Thesis). Staff Paper Number 75-24, Department of Agricultural Economics and Economics, Montana State University, Bozeman, December 1975.

TEACHING:

Courses Taught	Level
Financial Engineering	Senior
Agricultural Finance	Junior
Conception to Consumption	Senior
Farm & Ranch Management	Junior
Financial Economics	Senior; Graduate
Managerial Economics	Junior
Microeconomic Theory	Graduate
Production Economics	Senior
Quantitative Methods In Economics I	Senior; Graduate
Research Methodology	Graduate
Agricultural Finance	Junior
Introductory Economics	Freshman

OUTREACH:

For the last several years, presented to non-academic groups about 35 to 50 times per year.
Topics include:

- grazing policy on federal lands use and value of EPDs
- animal identification
- animal disease insurance
- brucellosis policy alternatives
- implications of changing demographics of Montana
- federal crop insurance topics
- agricultural land taxation
- K-12 school funding
- Montana's tax policy and spending policy
- Arrow's Theorem and the Iraq War
- teaching economics in high schools
- value

Other Teaching Activities:

- Graduate Committee: Kole Swanser, Lucannus Martin, Joel Shumacher, John Kuhling, Joe Vanek, Jian-yi Du, Arlen Smith, Patricia Pidruchney, Clark Jones, John MacArthur, Douglas Hart, Shen Zhihua, Ian Anderson, Jan Chovosta.
- Competitive Scholarship Program (1989–95)
- Faculty Advisor, MSU Ag Business Club (1977–79)
- MSU College of Agriculture Honor Roll for Outstanding Instruction (1978–79; 1979–80)

GRANTS:

- United States Department of Interior, 2013-2014, $28,259.
- Montana Taxpayers Association, 2012-2013, $35,000.
- Variety Private Donors, Project 2030, 2012-2013, $17,580.
- Variety Private Donors, Project 2030, 2008, $20,000.
- RMA-USDA, (through W&A), 2003-present, $50,000/year.
- RMA-USDA, (with J. Atwood), 2004-2005, $15,000.
- Economic Education (through MCEE) (with V. Smith), 2005, $10,000.
- Economic Issues Associated with Brucellosis Elimination in the GYA, APHIS-ERS/USDA (with D. Buschena), 2002-2003, ($50,000).
- Risk Management Agency (through WEA) (with J. Atwood), 2002, $50,000.
- USDA/CSREES (with J. Atwood), 2001, $92,000.
- USDA/CSREES (with J. Atwood), 2001, $43,000.
- USDA/CSREES (with J. Atwood), 1999-2001, $203,140.
- USDA/CSREES (with J. Atwood), 1999-2000, $70,451.
- USDA/CSREES (with B. Sowell), 1999-2000, $185,185.
- FCIC (with J. Atwood): Three grants 1998-2000, $102,000, $96,000, $140,000.
- NSF (with R. Rucker), 1998-2000, $102,039.
- FCIC (with J. A. Atwood): Two grants 1997-1999, $34,000, $26,000.
- CSREES/USDA (with R. Rucker): Information content of seller provided auction data, 1996-1998, $54,047.
- FCIC (with J.A. Atwood and A.E. Baquet): Four grants, 1994–1996, $99,334, $96,831, $60,400, $48,000.
- MSGH, Agricultural Taxation, 1992–1993, $3,000.
- FCIC, Whole Farm Crop Insurance (partial funding; with A. Baquet and J. Atwood), 1993–1994, $33,000.
- FCIC (with A. Baquet), Crop Insurance and Farm Structure, 1992–1993, $64,800.
- FCIC (with A. Baquet): To analyze the relationship between farm viability and crop insurance, 1992, $40,000.
- USDA (with C. Wambolt): To analyze high stocking rates to control sagebrush, 1990, $21,000.
- USDA (with C. Wambolt): To analyze high stocking rates to control sagebrush, 1987, $9,800.
- USDA (with C. Wambolt): To analyze various sagebrush treatments, 1985, $25,000.
- Montana Wheat & Barley Committee (partial funding; with A. Baquet): Whole Farm Crop Insurance 1993–1994, $19,000
- Montana Wheat and Barley Committee (with J. LaFrance): Economic potential of high-protein barley, 1984, $20,000.
- Soil Conservation Service (with J. B. Johnson): To study tillage practices in northeastern Montana, 1982, $20,000.
- U.S. Forest Service: To study the influence of Forest Service administered grazing on ranch income, 1979, $15,000.

PROFESSIONAL SERVICE:

- Regularly serves as a referee for *American Journal of Agricultural Economics, Journal of Agricultural and Resource Economics, Review of Agricultural Economics, Canadian Journal of Agricultural Economics,* and *Land Economics*
- Presented papers at several regional committee meetings (GPC-10, NCR-113, S-180, and Great Plains Resource Economics Committee)
- National Crop Insurance Research Committee Chair, 1999-2001
- Called to testify before many Legislative Committees; worked with DOR on budget and tax issues; contacted by over 50 legislators on various issues; provided many briefings at the request of multiple congressmen.
- *Journal of Agricultural and Resource Economics* Editorial Council (1995–1996).
- Editor of the *Journal of Agricultural and Resource Economics* (1991–1994)
- Western Agricultural Economics Council (1984–present)
  - Vice President, 1987–1988
  - President, 1988–1989

- Western Agricultural Economics Association
  - Director, 1985–1987
  - Selected Papers Committee, 1988
- NCR-113 — Farm and Financial Management (1980–1984)
- S-180 — Risk in Agriculture (1985–1988)
- GPC-10 Regional Committee — Farm Management and Production Economics (1980–1986)
  - Vice Chairman, 1981–1982
  - Chairman, 1982–1983

UNIVERSITY SERVICE/OUTREACH:

- Advisory Board, College of Business, University of Montana, 2007 to present
- Board of Directors for MCEE, 2005 to present
- Member RMA Quality Control Group, 2005
- Member at Large, Department Advisory Committee, 2005-2007
- Montana Tax Reform Committee Member, appointed by Governor, 2003-2005
- Montana Ag Land Advisory Committee Member, appointed by Governor, 2003-2005
- Search Committee Member for Dean, College of Letters and Sciences, 2002-2003
- Search Committee Chair for Associate Dean, College of Agriculture, 1999
- Search Committee Chair for Head of Animal and Range Science, 1997-1998
- Montana Agricultural Advisory Committee, appointed by Governor (1995–2001)
- University Grievance Committee, Chair (1996–1997)
- Department Head Search Committee, Chair (1995)
- University Grievance Committee (1993–1995)
- Department of Sociology P & T Committee (1992)
- Graduate Affairs Committee, Department of Agricultural Economics and Economics, (Chair, 1992–1996)
- Montana Science and Technology Committee (1991–1992, appointed by Governor)
- Montana Land Advisory Committee, State of Montana (1989–1993, appointed by Governor)
- Governor's Ad Hoc Committee on Taxation, State of Montana (1988–1990, appointed by Governor)
- MONTS Program Oversight Committee (1989–1991)
- University Outreach Committee, Montana State University (1989–1990)
- Social Science Core Course Committee, Montana State University (1989–1990)
- Steering Committee for Accreditation Review, Montana State University (1989–1990)
- University Teaching Education Committee (UTEC), Montana State University (1988–1989)
- University Financial Records System (FRS) Committee, Montana State University (1988–1989)
- Governor's Budget Committee, Technical Advisor (1985–1990)
- Preparation of Montana Farm Survey [with J. Saltiel], Montana State University (1988–2003)
- Department Head Advisory Committee, Department of Agricultural Economics and Economics, Montana State University (1979–1980; 1983–1984; 1984–1985)
- Graduate Affairs Committee, Department of Agricultural Economics and Economics, Montana State University (1980–1985) (Chair, 1982–1985)
- Farm Management Extension Committee, Montana State University (1978–1987)
- Scholarship Committee, College of Agriculture, Montana State University (1978–1983) (Chair, 1981–1983)
- Resident Instruction Committee, Department of Agricultural Economics and Economics, Montana State University (1978–1980)
- Chair, Master's Degree in Agricultural Management Committee, Department of Agricultural Economics and Economics, Montana State University (1979) — Ad hoc committee to develop an M.S. degree in agricultural management for the consideration of departmental faculty
- Teaching Improvement Committee, College of Agriculture, Montana State University (1978–1979)
- Chair, Graduate Program Review Committee, Department of Agricultural Economics, University of Nebraska (1977)—Ad hoc committee established to review the graduate and undergraduate programs and to make both general recommendations about the entire program and specific recommendations about courses and course content

- Testified before various Congressional and legislative hearings and meetings
- Many search and other University committees

December 2013

Randal R. Rucker

Agricultural Economics & Economics Department
Montana State University
Bozeman, MT 59717-2920
(406) 994-5644
FAX (406) 994-4838

9986 Happy Acres West
Bozeman, MT 59718
(406) 586-1798

EDUCATION:

- **Ph.D., Economics**, University of Washington, 1984.
- **M.S., Applied Economics**, Montana State University, 1980.
- **B.S., Economics**, Montana State University, 1977.

EXPERIENCE:

- Professor, Department of Agricultural Economics and Economics, Montana State University, 1996-present.
- Associate Professor, Department of Agricultural Economics and Economics, Montana State University, 1991-1996.
- Associate Professor, Department of Agricultural and Resource Economics, N.C. State University, 1990-1991.
- Associate Professor, Department of Economics and Business, N.C. State University, 1990-1991.
- Assistant Professor, Department of Economics and Business, N.C. State University, 1984-1990.
- Associate Appointment, Department of Forestry, N.C. State University, 1990-1991.
- Economist, Department of Interior, 1984.
- Research Fellowship, Sloan Foundation Grant for Study of the Regulation of Natural Resources, 1983.
- Research Assistant, University of Washington, 1980-1981.
- Instructor, University of Washington, 1979-1983.
- Research Associate, Montana State University, 1976, 1979, 1980, 1981.

PERSONAL DATA:

- Home Address: 9986 Happy Acres West, Bozeman, MT 59718
- Date of Birth: 04/13/54
- Status: Married, 3 children
- Citizenship: U.S.A.

PROFESSIONAL ACTIVITIES:

Fields:

- Applied Microeconomics/Regulation/Contracting
- Agricultural Economics
- Natural Resource/Forestry Economics

Teaching Experience:

- Principles
- Microeconomics (undergraduate, Master, and Ph.D.)
- Natural Resource Economics (graduate)
- Labor Economics
- Agricultural Marketing & Agricultural Policy

Professional Memberships:

- American Economic Association
- American Agricultural Economics Association
- Western Economics Association
- Western Agricultural Economics Association

Referee for:

- American Economic Review
- Journal of Law, Economics, and Organization
- National Science Foundation
- Journal of Law and Economics
- Review of Economics and Statistics
- Journal of Environmental Economics and Management
- American Journal of Agricultural Economics
- Land Economics
- International Review of Economics and Finance
- Western Journal of Agricultural Economics/Journal of Agricultural and Resource Economics
- Forest Science
- Journal of Institutional and Theoretical Economics
- Social Science Quarterly
- Review of Agricultural Economics
- Scandinavian Journal of Economics
- Canadian Journal of Forest Resources
- Resource and Energy Economics
- Review of Industrial Organization
- Canadian Journal of Agricultural Economics

Associate Editor for:

- Forest Science (1993-1995)
- American Journal of Agricultural Economics (1993-1997)

PUBLICATIONS:

Refereed Journal Articles:

- "Honeybee Pollination Markets and the Internalization of Reciprocal Benefits," with Walter N. Thurman and Michael Burgett, *American Journal of Agricultural Economics*, July 2012, 94(4): 956-977.
- "The End of the Federal Tobacco Program: Economic Impacts of the Deregulation of U.S. Tobacco Production," with A. Blake Brown and Walter N. Thurman, *Review of Agricultural Economics*, Winter 2007, 29(4): 635-655.
- "Estimating the Structure of Market Reaction to News: Information Events and Lumber Futures Prices," with Walter Thurman and Jonathan Yoder, *American Journal of Agricultural Economics*, May 2005, 87(2): 482-500.
- "The Fable of the Bees Revisited: Causes and Consequences of the U.S. Honey Program," with Walter N. Thurman, Mary Muth and Ching-Ta Chuang, *Journal of Law and Economics*, 2003, 46(2): 479-516.
- "Transaction Costs and Cattle Marketing: The Information Content of Seller-Provided Data at Cattle Auctions," with Jan Chvosta and Myles Watts, *American Journal of Agricultural Economics*, 2001, 83(2): 286-301.
- "Transaction Costs and the Collection of Information: Presale Measurement on Private Timber Sales," with Keith B. Leffler and Ian A. Munn, *Journal of Law, Economics, and Organization*, 2000, 16(1): 166-188.
- Munn, Ian A., and Randal R. Rucker, "Predicting Forestry Consultant Participation Based on Hedonic Characteristics of Timber Sales," *Journal of Forest Economics*, 1998, 4(2): 105-125.
- Rucker, Randal R., Walter N. Thurman, and Daniel A. Sumner, "Restricting the Market for Quota: An Analysis of Tobacco Production Rights with Corroboration from Congressional Testimony," *Journal of Political Economy*, 1995, 103(1): 142-175.
- Johnson, Ronald N., Randal R. Rucker, and Holly L. Lippke, "Expanding U.S. Log Export Restrictions: Impacts on State Revenues and Policy Implications," *Journal of Environmental Economics and Management*, 1995, 29: 197-213.
- Munn, Ian A. and Randal R. Rucker, "An Economic Analysis of the Difference Between Bid Prices on Forest Service and Private Timber Sales," *Forest Science*, 1995, 41(4): 823-840.
- Munn, Ian A., and Randal R. Rucker," The Value of Information Services in a Market for Factors of Production with Multiple Attributes: The Role of Consultants in Private Timber Sales," *Forest Science*, 1994, 40(3): 474-496.
- Leffler, Keith B., and Randal R. Rucker, "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," *Journal of Political Economy*, 1991, 99(5): 1060-1087.
- Rucker, Randal R., and Walter N. Thurman, "The Economic Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program," *Journal of Law and Economics*, 1990, 33(2): 483-515.
- Franklin, Carlyle, Dennis Hazel, Randal R. Rucker, and Gary Kronrad, "Thinning and Harvest Regimes for Yellow Poplar," *Southern Journal of Applied Forestry*, 1990, 14(3): 101-103.
- Rucker, Randal R., "The Effects of State Farm Relief Legislation on Private Lenders and Borrowers: The Experience of the 1930s," *American Journal of Agricultural Economics*, 1990, 72(1): 24-34.
- Rucker, Randal R., and K.B. Leffler, "To Harvest or Not to Harvest? An Analysis of Cutting Behavior on Federal Timber Sales Contracts," *Review of Economics and Statistics*, 1988, 70(2): 207-213.
- Rucker, Randal R., and L.J. Alston, "Farm Failures and Government Intervention: A Case Study of the 1930s," *American Economic Review*, 1987, 77(4): 724-30.

- Rucker, Randal R., and R.H. Nelson, "Federal Timber Sales Procedures: The Need for Reform," *Western Journal of Applied Forestry*, 1987, 2(1): 30-33.
- Rucker, Randal R., O. Burt, and J.T. LaFrance, "An Econometric Model of Cattle Inventories," *American Journal of Agricultural Economics*, 1984, 66(2): 131-44.

Books:

- Plowshares and Pork Barrels: The Political Economy of Agriculture, with E. C. Pasour, Jr., The Independent Institute, Oakland, California, 2005.

Published Abstracts:

- "The Information Content of Seller-Provided Presale Data in Cattle Auctions," with Jan Chvosta and Myles Watts, *American Journal of Agricultural Economics*, December 1997.
- "Indian and Non-Indian Salmon Fisheries: The Economic Effects of U.S. v. Washington," Peter H. Nickerson and Randal R. Rucker, *American Journal of Agricultural Economics*, December 1994.
- "U.S. Log Export Restrictions: Impacts and Welfare Implications," Ronald N. Johnson, Randal R. Rucker, and Holly L. Lippke, *American Journal of Agricultural Economics*, December 1993.
- "Presale Measurement in a Competitive Auction Framework: Cruising Expenditures on Private Timber Sales," Keith B. Leffler, Randal R. Rucker, and Ian A. Munn, *American Journal of Agricultural Economics*, December 1993.
- "The Value of Information Services in a Market for Factors of Production with Multiple Attributes: The Role of Consultants in Private Timber Sales," Ian A. Munn and Randal Rucker, *American Journal of Agricultural Economics*, December 1992.
- "The Side Effects of Supply Controls: Export Market Effects of Domestic Peanut Policy," Randal R. Rucker and Walter N. Thurman, *American Journal of Agricultural Economics*, December 1991.
- "Production Rights with Limited Transferability: A Case Study of the U.S. Tobacco and Peanut Programs," Randal R. Rucker, Walter N. Thurman, and Daniel A. Sumner, *American Journal of Agricultural Economics*, December 1990.
- "An Economic Analysis of the Determinants of Farm Failure Rates: 1912-1980," Lee J. Alston, Jeffrey T. LaFrance, and Randal R. Rucker, *American Journal of Agricultural Economics*, December 1989.
- "The Effects of State Farm Relief Legislation on Private Lenders: The Experience of the 1930s," Randal R. Rucker and Lee J. Alston, *American Journal of Agricultural Economics*, December 1987.

Papers in Collection:

- "The Growth of U.S. Farm Programs," with E. C. Pasour, Jr., Chapter 16 in *Government and the American Economy from Colonial Times to the Present*, University of Chicago Press, 2007.
- Rucker, Randal R., and Daniel A. Sumner, "Agriculture and Business Cycles," in *Encyclopedia of Business Cycles, Panics, Crashes and Depressions*, edited by David Glasner, Garland Publishing, Inc., 1997.
- Rucker, Randal R., Walter N. Thurman, and Robert B. Borges, "GATT and the U.S. Peanut Market," in Regulations and Protectionism Under GATT and NAFTA: Case Studies in North American Agriculture, Andrew Schmitz, ed., Westview Press, 1996.
- Leffler, Keith B., and Randal R. Rucker, "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," *Journal of Political Economy*, 1991, 99(5):1060-1087. Reprinted in Transaction Cost Economics: Policy and Applications, Oliver Williamson and Scott Masten, eds., Volume 2, Edward Elgar Publishing, 1995.
- Munn, Ian A., and Randal R. Rucker, "Testing for Endogenous Variables: A Timber Sale Example," in *Forest Economics on the Edge, Proceedings of the 24th Annual Southern Forest Economics*

Workshop, David Newman and MaryEllen Aronow, eds., Savannah, Ga., Sponsored by the Daniel B. Warnell School of Forest Resources, University of Georgia, March 27-29, 1994: 81-87.

- Munn, Ian A., and Randal R. Rucker, "The Effect of Forestry Consultants on Timber Sale Prices: A Price Decomposition Approach," in *Policy and Forestry: Design, Evaluation, and Spillovers - Proceedings of the 1993 Southern Forest Economic Workshop*, David N. Wear, ed., Duke University, Durham, N.C., April 21-23, 1993: 28-35.
- Rucker, Randal R., Walter N. Thurman, and Daniel A. Sumner, "An Economic Analysis of the Effects of Eliminating Restrictions on the Transfer of Tobacco Quota," in *Current Issues in Tobacco Economics*, Vol. 4, Tobacco Merchants Association of the United States, Inc., Princeton, NJ, 1991.
- Rucker, Randal R., and Price Fishback, "The Federal Reclamation Program: An Analysis of Rent-Seeking Behavior," by Terry Anderson, ed., *Water Rights: Scarce Resource Allocation, Bureaucracy and the Environment*, Pacific Institute for Public Policy Research, 1983.

Monographs, Research Reports, and Miscellaneous Publications:

- "Colony Collapse Disorder: The Market Response to Bee Disease," with Walter N. Thurman, *PERC Policy Series*, No. 50, January 2012.
- "Honey Bee Colony Mortality in the Pacific Northwest: Winter 2008/2009," with Dewey Caron, Michael Burgett and Walter N. Thurman, *American Bee Journal*, March 2010.
- "U.S. Pollination Markets: Recent Changes and Historical Perspective," with Stan Daberkow, Walter N. Thurman and Michael Burgett, *American Bee Journal*, January 2010, 35-41.
- "U.S. Honey Markets: Recent Changes and Historical Perspective," with Stan Daberkow, Walter N. Thurman and Michael Burgett, *American Bee Journal*, December 2009, 1125-1129.
- "Honey Bee Colony Mortality in the Pacific Northwest (USA)," Winter 2007/2008, with Michael Burgett and Walter N. Thurman, *American Bee Journal*, June 2009, 573-575.
- "Economics and Honeybee Pollination Markets," with Walter N. Thurman and Michael Burgett, *American Bee Journal*, April 2004, 269-71.
- Chvosta, Jan, Randal R. Rucker, and Walter N. Thurman, "Texas Post-FAIR: The Big Get Bigger and the Small Decline," *The Peanut Farmer*, May 2001, pp.10-11.
- Chvosta, Jan, Randal R. Rucker, and Walter N. Thurman, "Post-FAIR: How has Peanut Production Changed Since 1996?" *The Peanut Farmer*, April 2001, pp. 14-15.
- Rucker, Randal R., Walter N. Thurman, and Robert B. Borges, "The Effects of the Uruguay Round GATT on U.S. Peanut Markets," CARD GATT Research Paper Series, #92-GATT 23, Iowa State University, July 1994.
- Rucker, Randal R., "Estimating the Economic Benefits to the Wood Products Industry of Reductions in Ambient Ozone Levels," written for the U.S. Environmental Protection Agency, August 1988.
- Rucker, Randal R., M. Copeland and R. Stroup, "Estimation of Amenity Values as Opportunity Costs for Energy Related Water Use in Montana," Montana University Joint Water Resources Research Center, Report No. 81, October 1976.

Book Reviews:

- Rucker, Randal R., Review of Plowing Ground in Washington: The Political Economy of U.S. Agriculture (written by B. Delworth Gardner), in *The Independent Review: A Journal of Political Economy*, Summer 1997, pp. 139-143.
- *The Timber Bubble that Burst: Government Policy and the Bailout of 1984* by Joe P. Mattey. *Forest Science*, cowritten with W.F. Hyde, February 1992, 38(1): 211-212.
- *Rivers of Empire: Water Aridity, and the Growth of the American West* by Donald Worster. *Journal of Economic History*, 1986, 46(4): 1099-1100.

Departmental and Other Publications:

- Rucker, Randal R., Walter N. Thurman and Michael Burgett. "Colony Collapse: The Economic Consequences of Bee Disease," Staff Paper 2012-01 (Update of Staff Paper 2011-01), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, April 2012.
- Parker, Dominic, Randal R. Rucker, and Peter N. Nickerson. "The Microeconomics of a Natural Resource Boom: Evidence from the Washington Salmon Tribal Fishery," Staff Paper 2012-02 (Update of Staff Paper 2011-3), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, August 2012.
- Parker, Dominic, Randal R. Rucker, and Peter N. Nickerson. "Property Rights and Natural Resource Curses: Micro Evidence from a Tribal Fishery," Staff Paper 2012-03, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, November 2012.
- Avalos, Roger, Timothy Fitzgerald, and Randal R. Rucker, "Measuring the Effects of Natural Gas Pipeline Constraints on Regional Pricing and Market Integration," Staff Paper 2012-03, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, November 2012.
- Elizondo, Vanessa, Timothy Fitzgerald, and Randal R. Rucker. "You Can't Drag Them Away: An Economic Analysis of the Wild Horse and Burro Program," Staff Paper 2011-02, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, October 2011.
- Rucker, Randal R. and Walter N. Thurman," Contracting for Pollination Services: Birds Do It, Bees Do It . . . Let's Specialize and Exchange," Staff Paper 2010-4, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, November 2010.
- Rucker, Randal R., Walter N. Thurman, and Michael Burgett, "The Economics of Honeybee Pollination Markets," Staff Paper 2010-3 (Revision of Staff Paper Nos. 2008-2 and 2006-1), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, October 2010.
- Nickerson, Peter H., Nick Parker, and Randal R. Rucker, "Do Tribes Benefit from Windfall Fishing Allocations? The Role of Property Rights with Evidence form US. v. Washington," Staff Paper 2010-2, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, July 2010.
- Leffler, Keith B. , Randal R. Rucker and Peter Malishka, "Per Pound or Not Per Pound? The Role of Transaction Costs in Fresh Produce Pricing," Staff Paper 2010-1 (revision of Staff Paper No. 2001-05), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, April 2010.
- Leffler, Keith B., Randal R. Rucker, and Ian Munn, "The Choice Among Sales Procedures: Auction vs. Negotiated Sales of Private Timber," Staff Paper 2008-1 (Revision of Staff Paper No. 2006-3), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, April 2008.
- Rucker, Randal R., and E. C. Pasour, Jr., "The Growth of U.S. Farm Programs," Staff Paper 2006-2, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, December 2006.

- Muth, Mary K., Randal R. Rucker, Walter N. Thurman, and Ching-Ta Chuang, "The Fable of the Bees Revisited: Causes and Consequences of the U.S. Honey Program," Staff Paper 2002-3 (Revision of Staff paper No. 2001-3), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, September 2002.
- Rucker, Randal R., Walter N. Thurman, and Jonathan Yoder, "Estimating the Structure of Market Reaction to News: Information Events and Lumber Futures Prices," Staff Paper 2002-5 (Revision of Staff Paper No. 2000-9), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, February 2002.
- Leffler, Keith B. , Randal R. Rucker, and Peter Malishka, "Per Pound or Not Per Pound? An Economic Analysis of Produce Pricing Practices," Staff Paper 2001-5, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, November 2001.
- Chvosta, Jan, Randal R. Rucker, and Myles Watts, "Transaction Costs and Cattle Marketing: The Information Content of Seller-Provided Data at Cattle Auctions," Staff Paper 2000-7 (revision of Staff Paper 97-3), Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, February 2000.
- Anderson, Terry L., Daniel K. Benjamin, Peter Malishka, and Randal R. Rucker, "Private Leasing of Public Resources: The Effects of Changes in Property Rights Regimes at the Bureau of Reclamation's Canyon Ferry Cabin Program," Staff Paper No. 98-2, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, December 1998.
- Leffler, Keith B., Randal R. Rucker, and Ian A. Munn, "Transaction Costs and the Collection of Information: Presale Measurement on Private Timber Sales," Staff Paper No. 98-1, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, December 1998.
- Munn, Ian A. and Randal R. Rucker, "Predicting Forestry Consultant Participation Based on Hedonic Characteristics of the Sale," Staff Paper No. 97-4, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, March 1997.
- Chvosta, Jan, Randal R. Rucker, and Myles Watts, "The Information Content of Seller-Provided Presale Data in Cattle Auctions," Staff Paper No. 97-3, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, August 1997. Macaroni and cheese tastes really good.
- Muth, Mary, Walter N. Thurman, Randal R. Rucker, and Ching-Ta Chuang, "The Fable of the Bees Revisited: A Post Mortem of the U.S. Honey Program," Staff Paper No. 97-5, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, April 1997.
- Rucker, Randal R., and Brenda L. Brenner, "An Analysis of Bidding Behavior at U.S. Forest Service Timber Auctions," Staff Paper No. 96-3, Dept. of Agricultural Economics and Economics, Montana State University-Bozeman, December 1996, pp. 134.
- "Transaction Costs and the Collection of Information: Presale Measurement on Private Timber Sales," (with Keith B. Leffler and Ian A. Munn), Discussion Paper Series #95-02, Institute for Economic Research, University of Washington, January 1995.
- "The Economic Effects of Restricting the Transfer of Production Rights," (with Walter N. Thurman and Daniel A. Sumner), Staff Paper 93-10, Dept. of Agricultural Economics and Economics, Montana State University, October 1993.
- "An Economic Analysis of the Differences Between Bid Prices on Forest Service and Private Timber Sales," (with Ian Munn), Staff Paper 93-9, Dept. of Agricultural Economics and Economics, Montana State University, September 1993.
- "U.S. Log Export Restrictions: Impacts and Welfare Implications," (with Ronald N. Johnson and Holly L. Lippke), Staff Paper 93-7, Department of Agricultural Economics and Economics, Montana State University, May 1993.

- "The Value of Information Services in a Market for Factors of Production with Multiple Attributes: The Role of Consultants in Private Timber Sales" (with Ian Munn), Staff Paper 93-5, Department of Agricultural Economics and Economics, Montana State University, April 1993.
- "The Political Economy of Restrictions on the Transfer of Production Rights: A Case Study of the U.S. Flue-Cured Tobacco Program," Staff Paper 92-9, Department of Agricultural Economics and Economics, Montana State University, October 1992.
- Rucker, Randal R., and Raymund Fabre, "Lease Rates and Sale Prices for Peanut Poundage Quota: 1978-1987," Economic Information Report No. 78, Department of Economics and Business, North Carolina State University, February 1989.
- Rucker, Randal R., and Walter N. Thurman, "The Economic Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program," Working Paper no. 123, Department of Economics and Business, North Carolina State University, May 1988.
- Rucker, Randal R., "The U.S. Peanut Program: History and Recent Changes," *Tar Heel Economist*, N.C. Agricultural Extension Service, N.C. State University, February 1988.
- Rucker, Randal R., "The Effects of State Farm Relief Legislation on Private Lenders: The Experience of the 1930s," Working Paper No. 101, Department of Economics and Business, North Carolina State University, May 1987.
- Rucker, Randal R., "Historical Trends in Farm Failures," *Tar Heel Economist*, N.C. Agricultural Extension Service, N.C. State University, October 1986.
- Rucker, Randal R., "Causes of Farm Failures and Effectiveness of Government Programs in Alleviating Stress," *Tar Heel Economist*, N.C. Agricultural Extension Service, N.C. State University, October 1986.
- Rucker, Randal R., "Forecasts of North Carolina Agricultural Commodity Prices and Yields, 1985-2030," Economics Special Report No. 92, Department of Economics and Business, North Carolina State University, September 1986.
- Rucker, Randal R., and Lee Alston, "The Effectiveness of Government Policies to Alleviate Agricultural Distress: A Case Study of the 1930s," Working Paper No. 85, Department of Economics and Business, North Carolina State University, June 1986.
- Rucker, Randal R., and Keith Leffler, "To Harvest or Not to Harvest? An Analysis of Cutting Behavior on Federal Timber Sales Contracts," Working Paper No. 86, Department of Economics and Business, North Carolina State University, June 1986.

Popular Press Publications:

- Randal R. Rucker and Walter N. Thurman, "Blessed Are the Beekeepers," *Wall Street Journal*, June 22, 2011.
- Randal R. Rucker and Peter H. Nickerson, "Seattle's bag tax is a bad idea without substantive environmental impact," The Seattle Times, August 24, 2009.
- Randal R. Rucker and Walter N. Thurman, "Counterproductive Price Gouging Laws," *Raleigh News and Observer*, October 11, 2008.
- E. C. Pasour, Jr. and Randal R. Rucker, "The Schizophrenia of U.S Farm Policy," *Investor's Business Daily*, April 22, 2008.
- E. C. Pasour, Jr. and Randal R. Rucker, "Big ethanol push in U.S. is pork barrel boondoggle," *Billings Gazette*, July 14, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "Ethanol a tax-financed boondoggle," *Montana Standard*, Butte, MT, July 27, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "Ethanol as pork," *Salt Lake Tribune*, July 26, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "Ethanol as pork," *The Tampa Tribune*, July 30, 2007.

- E. C. Pasour, Jr. and Randal R. Rucker, "Ethanol as Pork," *Yankton Press and Dakotan*, August 3, 2007.
- The op-ed on ethanol were also published during July and August of 2007 in the *Modesto Bee* (Sacramento, CA), the *Centre Daily Times* (State College, PA), *Virginia Pilot* (Norfolk, VA), *Latin Business Chronicle*, *Southern Illinoisian* (Carbondale, IL), *Post Star* (Glen Falls, NY), *Butler Eagle* (PA), *Columbian* (Vancouver, WA), *News-Star* (Shawnee, OK)
- E. C. Pasour, Jr. and Randal R. Rucker, "Bumper crop: Farm subsidies for the rich," *Charleston (WV) Gazette*, August 2, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "Schizophrenic U.S. farm policy," *Yankton Press & Dakotan*, September 28, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "U.S. farm policy works against itself," *Billings Gazette*, September 28, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "American Farm Policy is schizophrenic," *Youngstown Vindicator*, Youngstown (OH), September 28, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "U.S. farm policies too often at cross-purposes," *Pittsburgh Tribune-Review*, September 28, 2007.
- E. C. Pasour, Jr. and Randal R. Rucker, "Current farm policy doesn't make sense," *AgWeek* (Grand Forks, ND), Oct. 22, 2007.
- The op-ed on schizophrenic farm policies was also published during the fall of 2007 in the Corpus Christi (TX) *Caller-Times*, Rochester (MN) *Post-Bulletin*, Boulder (CO) *Daily Camera*, *Taiwan News*, and *AgroInsurance.com*.

HONORS AND AWARDS:

- Agricultural and Applied Economics Association Award for Best Journal Article in the *American Journal of Agricultural Economics*, 2012.
- American Agricultural Economics Association Award for Quality of Research Discovery, 1996.
- Western Agricultural Economics Association Award for Outstanding Published Research (Honorable Mention), 1996.
- American Agricultural Economics Association Award for Outstanding Master's Thesis, 1980.
- Western Agricultural Economics Association Award for Outstanding Master's Thesis (Honorable Mention), 1980.
- Outstanding Academic Achievement, Montana State University, 1977.
- Academic All-American (Basketball, Second Team), 1976.

CURRENT RESEARCH:

- "Estimates of U.S. Private Oil and Natural Gas Royalties," with Timothy Fitzgerald, November 2013.
- "Colony Collapse Disorder: The Economic Consequences of Bee Disease," with Walter N. Thurman and Michael Burgett, April 2012.
- "Pipeline Constraints in Wholesale Natural Gas Markets: Effects on Regional Regional Pricing and Market Integration," with Roger Avalos and Timothy Fitzgerald, December 2012.
- Parker, Dominic, Randal R. Rucker, and Peter N. Nickerson. "Property Rights and Natural Resource Curses: Micro Evidence from a Tribal Fishery," Staff Paper 2012-03, Dept. of Agricultural Economics and Economics, Montana State University, Bozeman, MT, November 2012.

- "The Microeconomics of a Natural Resource Boom: Evidence from the Washington Salmon Tribal Fishery," with Dominic Parker and Peter H. Nickerson, August 2012.
- "You Can't Drag Them Away: An Economic Analysis of the Wild Horse and Burro Program," with Vanessa Elizondo and Timothy Fitzgerald, October 2011.
- "Contracting for Pollination Services: Birds Do It, Bees Do It . . . Let's Specialize and Exchange," with Walter N. Thurman, November 2010.
- "Per Pound or Not Per Pound? The Role of Transaction Costs in Fresh Produce Pricing," with Keith B. Leffler and Peter Malishka. April 2010.
- "The Choice Among Sales Procedures: Auction vs. Negotiated Sales of Private Timber," with Keith Leffler and Ian Munn.
- "Welfare Economics and the Economic Value of Pollination," with Walter N. Thurman and Daniel A. Sumner.
- "Determinants of Seller Choice Between Auction and Negotiation: An Empirical Application to Cattle Markets," with Kole Swanser.
- "An Economic Analysis of the Enactment of Anti-Price Gouging Laws," with Cale Davis.
- "The End of Supply Controls: The Economic Effects of Recent Changes in Federal Peanut Policy," with Walter N. Thurman and Jan Chvosta..
- "Private Leasing of Public Resources: The Effects of Changes in Property Rights Regimes at the Bureau of Reclamation's Canyon Ferry Cabin Program," with Terry Anderson, Daniel K. Benjamin, and Peter Malishka.
- "Endogenous Policy Dynamics, the Visibility of Rents, and Changes in the Transferability of Production Rights: The Case of Flue-Cured Tobacco."
- "The Economics of Artificial Insemination Regulations in the Equine Breeding Industry," with Daniel K. Benjamin and Valerie A. Thresher, in progress.
- "An Economic Analysis of Changing Appraisal Methods on Forest Service Timber Sales," with Brenda Brenner.

GRANTS:

- Earhart Foundation Fellowship Research Grant, "The Microeconomics of an Open Access Fishery: Evidence from Washington State, 2011-2012" with Nick Parker, $17,500.
- USDA, Cooperative Agreement, Grant to study the economic impacts of Colony Collapse Disorder, 2007-2009, $40,000, with Walter N. Thurman and Michael Burgett.
- USDA, Tribal Research College Competitive Grants Program: Grant to study the beef marketing practices of American Indians, 2004-2006, $150,000, with Vince Smith and Gary Brester..
- USDA, NRI Competitive Grants Program: Grant to study the causes and consequences of the U.S. honey program and the economics of pollination markets, 2001-2006, $135,000.
- National Science Foundation Grant: Grant to study the choice among sales procedures (auction vs. negotiated) for private timber and for cattle, 1998-2003, $102,039.
- USDA, NRI Competitive Grants Program: Grant to study the impacts of policies regarding the transfer of production rights in quota-based commodity programs, 1998-2003, $52,000.
- Cooperative Agreement with U.S. Forest Service: Grant to study the choice among sales procedures (auction vs. negotiated) for private timber, 1997-99, $12,000.
- USDA, NRI Competitive Grants Program: Grant to study the information content of seller-provided presale data in cattle auctions, 1996-1999, $54,047.
- Trade Research Center, MSU-Bozeman: Grant to study impacts of Canadian forestry policies on U.S. lumber prices, 1996-1998, $29,982.

- Cooperative Agreement with U.S. Forest Service: Grant to study the determinants of cruising practices on private timber sales, 1994-1995, $12,400.
- Political Economy Research Center: Grant to examine Indian vs. nonIndian allocations in the Washington salmon fishery (with Peter Nickerson), 1994, $1,500.
- Cooperative Agreement with U.S. Forest Service: Grant to study bidding patterns and competition on Forest Service timber sales in the West, 1993-95, $33,964.
- Political Economy Research Center: Grant to examine the determinants of lumber price movements, 1993, $1,500.
- Cooperative Agreement with the U.S. Forest Service: Grant to contrast the determinants of bid prices on private and Forest Service timber-harvesting contracts (with Ian Munn), 1991-92, $10,900.
- Political Economy Research Center: Grant to study the political economy of changes in restrictions on transferability of tobacco quota, 1991, $12,000.
- Political Economy Research Center: Grant to study the determinants of presale measurement expenditures on private timber sales, 1991, $2,000.
- Cooperative Agreement with U.S. Forest Service: Grant to study the determinants of bid prices on private timber-harvesting contracts (with Ian Munn), 1990-92, $11,900.
- Political Economy Research Center: Grant to study economic effects of restrictions on transferability of peanut and tobacco quota (with D. Sumner and W. Thurman), 1988-90, $1,500.
- Cooperative Agreement with USDA, ERS: Grant to study economic effects of restrictions on transferability of peanut and tobacco quota (with D. Sumner and W. Thurman), 1988-90, $15,000.
- USDA Research Apprenticeship Program (with M. Walden), 1988.
- Political Economy Research Center: Grant for the study of private timber sales contracts, 1986-87, $2,000.

SEMINARS AND PRESENTATIONS:

- "The Microeconomics of a Natural Resource Boom: Evidence from the Washington Salmon Tribal Fishery," with Dominic Parker and Peter H. Nickerson, August 2012.
- "Colony Collapse Disorder: The Economic Consequences of Bee Disease," co-authored with Walter N. Thurman and Michael Burgett, School of Economic Sciences, Washington State University, April 6, 2012.
- "Colony Collapse Disorder: The Economic Consequences of Bee Disease," co-authored with Walter N. Thurman and Michael Burgett, Department of Agricultural Economics and Economics, Montana State University, March 21, 2012.
- "Colony Collapse: The Economic Consequences of Bee Disease," co-authored with Walter N. Thurman and Michael Burgett, Property and Environment Research Center, July 21, 2011.
- "Contracting for Pollination Services: Birds Do It, Bees Do It . . . Let's Specialize and Exchange," co-authored with Walter N. Thurman. Presented at conference titled "Contracting for Ecosystem Services," held at The Carolina Inn in Chapel Hill, NC, November 8-10, 2010.
- "Per Pound or Not Per Pound? The Role of Transaction Costs in Fresh Produce Pricing," co-authored with Peter Malishka and Keith Leffler, Department of Economics, University of Montana, Missoula, October 1, 2010.
- "Do Tribes Benefit from Windfall Fishing Allocations? The Role of Property Rights with Evidence from U.S. v. Washington," co-authored with Dominic Parker and Peter Nickerson. Presented at workshop titled "The Role of Property Rights and Institutions in North American Indian Economies," August 8 - 10, 2010, at the Property and Environment Research Center.

- "The Alaskan Crab Rationalization Program: Experiences of the First Two Seasons," Property and Environment Research Center, July 10, 2007.
- "Per Pound or Not Per Pound? The Role of Transaction Costs in Fresh Produce Pricing," Department of Agricultural Economics and Economics, Montana State University, Bozeman, November 2001.
- "Pollination Markets," Brown-bag Lunch Seminar, Department of Agricultural Economics and Economics, Montana State University, Bozeman, September, 2001.
- "By the Pound or By the Each? The Role of Transaction Costs in Fresh Produce Pricing," Western Economics Association Annual Meetings, San Francisco, July 2001.
- "By the Pound or By the Each? An Economic Analysis of Produce Pricing Practices," Department or Agricultural and Resource Economics and Department of Economics, North Carolina State University, May 2000.
- "The Information Content of Seller-Provided Presale Data in Cattle Auctions,"Department of Economics, Northern Arizona University, Flagstaff, AZ, March 1998.
- "The Fable of the Bees Revisited: A Post Mortem of the U.S. Honey Program," National Economics Symposium, University of Arizona, Tucson, AZ, May 1997.
- "The Fable of the Bees Revisited: A Post Mortem of the U.S. Honey Program," Department of Agricultural Economics and Economics, Montana State University, Bozeman, April 1997.
- "Restricting the Market for Quota: An Analysis of Tobacco Production Rights with Corroboration from Congressional Testimony," Economic and Legal Organization Workshop, University of Chicago, February 1995.
- "Presale Measurement in a Competitive Auction Framework: Cruising Expenditures on Private Timber Sales," Department of Agricultural Economics and Economics, Montana State University, Bozeman, November 1994.
- "Indian and Non-Indian Salmon Fisheries: The Economic Effects of U.S. v. Washington," American Agricultural Economics Association Meetings, San Diego, August 1994.
- "The Effects of the Uruguay Round GATT on U.S. Peanut Markets," Conference on Canadian Supply Management in Transition Towards the 21st Century, McGill University, St. Anne De Bellevue, Quebec, June 1994.
- "U.S. Log Export Restrictions: Impacts and Welfare Implications," American Agricultural Economics Association Meetings, Orlando, Florida, August 1993.
- "Presale Measurement in a Competitive Auction Framework: Cruising Expenditures on Private Timber Sales," American Agricultural Economics Association Meetings, Orlando, Florida, August 1993.
- "Presale Measurement in a Competitive Auction Framework: Cruising Expenditures on Private Timber Sales," Western Economic Association Meetings, Lake Tahoe, Nevada, June 1993.
- "The Economic Effects of Restricting the Transfer of Production Rights under Quota-Based Commodity Supply Control Programs," Department of Agricultural Economics and Economics, Montana State University, April 1993.
- "The Political Economy of Restrictions on the Transfer of Production Rights: A Case Study of the U.S. Flue-Cured Tobacco Program," Western Economic Association Meetings, San Francisco, July 1992.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," Department of Agricultural Economics, University of Arizona, November 1990.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," Department of Agricultural Economics and Economics, Montana State University, October 1990.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," Albers School of Business, Seattle University, October 1990.

- "Production Rights with Limited Transferability: A Case Study of the U.S. Tobacco and Peanut Programs," Annual AAEA meetings, Vancouver, B.C., August 1990.
- "Production Rights with Limited Transferability: A Case Study of the U.S. Tobacco and Peanut Programs," Agricultural Economics Workshop, NCSU, July 1990.
- "Timber-Harvesting Contracts: The Effects of Contract Terms and Sales Procedures on Revenues and Purchaser Incentives," World Bank, Washington, D.C., May 1990.
- "An Economic Analysis of the Determinants of Farm Failure Rates, 1912-1980," Agricultural Economics Workshop, NCSU, April 1990.
- "An Economic Analysis of the Determinants of Farm Failure Rates, 1912-1980," Department of Economics and Agricultural Economics, Montana State University, March 1990.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber-Harvesting Contracts," Economic and Legal Organization Workshop, University of Chicago, November 20, 1989.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber Harvesting," National Bureau of Economic Research, Conference on Topics in Industrial Organization, Cambridge, Massachusetts, August 1989.
- "Transaction Costs and the Efficient Organization of Production: A Study of Timber Harvesting," Natural Resources/Industrial Organization Workshop, NCSU, October 1988.
- "The Economic Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program," Southern Agricultural Economics Association Annual Meetings, New Orleans, February 1988.
- "The Effects and Side Effects of Supply Controls: The Simple Analytics of the U.S. Peanut Program," Department of Economics, Clemson, October 1987.
- "The Effects of State Farm Relief Legislation on Private Lenders: The Experience of the 1930s," American Agricultural Economics Association Annual Meetings, Lansing, Michigan, August 1987.
- "The Economic Effects of the Peanut Program," Department of Economics and Agricultural Economics, Montana State University, April 1987.
- "Chapter 12: Impact on the Farm Economy," Keynote Speaker at seminar sponsored by the Center for the Study of Market Alternatives, Caldwell, ID, April 1987.
- "The Effects of State Farm Relief Legislation on Private Lenders: The Experience of the 1930s," Agricultural Economics Workshop, NCSU, January 1987.
- "The Longer View of Farm Failures," American Feed Industry Association Annual Meeting, October 1986.
- "The Dynamics of Farm Failures and the Effects of Government Relief Programs, 1925-1939," Center for Study of Public Choice, George Mason University, October 1985.
- "The Dynamics of Farm Failures and the Effects of Government Relief Programs, 1925-1939," American Agricultural Economics Association Annual Meetings, Iowa, August 1985.
- "Farm Failures During the Interwar Period," Agricultural Economics Workshop, NCSU, April 1985.
- "Are Public Timber Sales Contracts Too Short?" Forestry Economics Discussion Group, NCSU, March 1985.
- "Below Cost Timber Sales," Conference on the Future of N.C. National Forests, Duke University, November 1984.

Montana State University Thesis Committees (Chaired or Co-Chaired)

- Shawn E. Regan
  "Does Wilderness Matter? An Examination of the Political Causes and Economic Consequences of Wilderness Designation," February 2013.
- Christopher Lawrence Watson
  "An Economic Analysis of National Park Visitation Rates," May 2013.
- Roger Avalos G.
  "Pipeline Constraints in Wholesale Natural Gas Markets: Effects on Regional Pricing and Market Integration," January 2012.
- Vanessa Valentina Elizondo
  "An Economic Analysis of the Wild Horse and Burro Program," Spring 2011.
- Amy Joanne Purdie
  "Market Value of Green Construction: A Case Study of Colorado's Built Green and Energy Star Certification Programs," Fall 2009.
- Cale Wren Davis
  "An Analysis of the Enactment of Anit-Price Gouging Laws," May 2008
- Kole Swanser
  "Determinants of Seller Choice Between Auction and Negotiation: An Empirical Application to Cattle Markets," April 2005.
- Peter Malishka
  "Measurement Costs and Pricing Methods in the Retail Produce Market," May 1999.
- Jan Chvosta
  "The Information Content of Best Seller-Provided Presale Data in Cattle Auctions," January 1997.
- Valerie Anne Thresher
  "The Economics of Artificial Insemination Regulations in the Equine Breeding Industry: Monopoly Versus Transaction Costs Explanations," December 1996.
- Brenda Lee Brenner
  "An Analysis of Bidding Behavior at U.S. Forest Service Timber Auctions," May 1996.
- Cory Scott Finnell
  "Determinants of Fishing Performance: The Washington State Salmon Fishery," December 1995.
- Jonathan Yoder
  "The Effects of Spotted Oil Litigation on National Lumber Markets," August 1994.
- Holly Linn Lippke (Professional Paper Option)
  "The Economic Effects of the Forest Resources Conservation and Shortage Relief Act of Timber Prices," January 1993.
- Rodney Philip Hide (Professional Paper Option)
  "Monopolizing Individual Transferable Quota: Theory and Evidence," July 1992.

Montana State University Thesis Committees (Committee Member)

- Bryan James Leonard
  "Which Came First, Laws or Lobbyists? An Empirical Investigation of Environmental Regulation and Interest Group Formation," April 2012.
- Mark Alan Berreth
  "The Political Economy of Prescribed Fires: A Land Agency's Decision to Burn," Spring 2010.
- Fritz Baird
  "Montana Agricultural Land Prices: An Evaluation of Recreational Amenities and Production Characteristics," Spring 2010.
- Tyler James Wiltgen
  "An Economic History of the United States Sugar Program," December 2007.
- Frank Chase Cook
  "An Empirical Analysis of Hunting Leases by Timber Firms," May 2007.
- Tyler Joseph Kruzich
  "Why Do Households Cultivate Landraces?: Wheat Variety Selection and In Situ Conservation in Turkey," May 2006.
- Adrienne M. Ohler
  "Prescription Drug Price Dispersion in Heterogeneous Markets," March 2005.
- John Kuhling
  "The Effects of Optional Units on Crop Insurance Indemnity Payments," January 2002.
- Andrew J. Seessel
  "The Effects of Transaction Costs on Northern Plains Oil Unitization Agreements," April 2000.
- Alexander William Vedrashko
  "The Alchian and Allen Theorem: Theory and Evidence," February 1998.

February, 2013

JOSEPH A. ATWOOD

Professor: Agricultural Economics & Economics Dept.
Montana State University
Bozeman, MT 59717-0292
(406)-994-5614

5274 Cimmeron Drive
Bozeman, MT 59715
(406) 586-4614

EDUCATION:

Ph.D., Agricultural Economics (1985), Graduate College, University of Nebraska, Lincoln.
- Areas of Study: *Production Economics, Risk Management and Finance*

M.S., Agricultural Economics (1980), Graduate College, University of Nebraska, Lincoln.
- Areas of Study: *Resources and Energy Production, Production Economics*

B.S., Animal Science-Agri Business Option (1978), College of Agriculture, University of Nebraska, Lincoln.

A.A. (1976), York College, York, Nebraska.

CLASSES TAUGHT AT MONTANA STATE UNIVERSITY:

ECON 201	-- Microeconomics
ECNS 204	-- Microeconomics
AGEC 341	-- Farm and Ranch Management
AGBE/ECNS 345	-- Agricultural Finance
ECON 400	-- Seminar: Mathematical Economics
ECON 400	-- Seminar: Special Topics in Quantitative Economics
ECNS 491	-- Financial Engineering 1
AGEC 467	-- Quantitative Methods in Economics
ECON 500	-- Graduate Seminar: Mathematical Economics
ECON 500	-- Graduate Seminar: Special Topics in Quantitative Economics

CLASSES TAUGHT AT UNIVERSITY OF NEBRASKA-LINCOLN:

AECN 896 -- Introduction to R (Spring 2008)

PUBLICATIONS:

Refereed Journal Articles:

Shaik, S.*, J.A. Atwood, and G. A. Helmers. "Did 1933 New Deal Legislation Contribute to Farm Real Estate: Regional Analysis." Journal of Policy Modeling. 34, no. 6(2012): 801-816.

Shaik, Saleem., Ashok K. Mishra, and Joseph Atwood. "Aggregation Issues in the Estimation of Nonparametric Linear Programming Productivity Measures." *Journal of Applied Economics.* 15, no. 1 (2012): 169-187.

Buschena, David E., and Joseph A. Atwood. "Evaluation of Similarity Models for Expected Utility violations". *Journal of Econometrics*. 162 (2011):105-113.

Brester, G., J. M. Marsh., and J. Atwood. "Evaluating the Farmer's-Share-of-the-Retail-Dollar Statistic." *Journal of Agricultural and Resource Economics.* 34, no. 2. (2009):213-236

Buschena, David E., David Zilberman, and Joseph A Atwood. "Risk Attitudes Over Income With Discrete Status Levels." *Review of Agricultural Economics*. 29 (Fall, 2007):405-411

Atwood, J., J. Robison-Cox, and S. Shaik. "A Statistical Examination of 'Yield Switching' Fraud in the Federal Crop Insurance Program." *American Journal of Agricultural Economics* 88, no. 2 (May 2006) 365-81.

Shaik, S., J. Atwood, and G. Helmers. "The Evolution of Farm Programs and their Contribution to Agricultural Land Values." *American Journal of Agricultural Economics.* 87, no. 5 (Dec. 2005): 1190-97.

Brester, G.W., J.M. Marsh, and J. Atwood. "Distributional Impacts of Country-of-Origin Labeling in the U.S. Meat Industry." *Journal of Agricultural and Resource Economics* 24, no. 2 (2004): 206-27.

Atwood, J., S. Shaik, and M.J. Watts. "Are Crop Yields Normally Distributed?: A Reexamination." *American Journal of Agricultural Economics* 85, no. 4 (2003): 888-901.

Atwood, J., and D.E. Buschena. "Evaluating the Magnitudes of Financial Transaction Costs on Risk Behavior." *Agricultural Systems* 75, no. 2-3 (2003): 235-50.

Atwood, J., S. Shaik, and M.J. Watts. "Can Normality of Yields be assumed for Crop Insurance?" *Canadian Journal of Agricultural Economics* 50, no. 2 (2002): 171-84.

Atwood, J., and G.A.Helmers. "Examining Quantity and Quality Effects of Restricting Nitrogen Applications to Feedgrains." *American Journal of Agricultural Economics* 80 (1998): 369-81.

Atwood, J., M.J. Watts, and A.E. Baquet. "An Examination of the Effects of Price Supports and Federal Crop Insurance upon the Economic Growth, Capital Structure, and Financial Survival of Wheat Growers in the Northern High Plains." *American Journal of Agricultural Economics* 78, no. 1 (1996): 212-24.

Atwood, J. "Constant Dollar Financial Statements." *Review of Agricultural Economics* 15, no. 1 (1993): 157-66.

Atwood, J. "Determining Firm Specific Values for Risky Assets." *Western Journal of Agricultural Economics* 15, no. 2 (1990): 196-203.

Hatch, V., J. Atwood, and J. Segar. "An Application of Safety-First Probability Limits in a Discrete Stochastic Farm Management Programming Model." *Southern Journal of Agricultural Economics* 21, no. 1 (1989): 65-72.

Atwood, J., M.J. Watts, G.A. Helmers, and L.J. Held. "Incorporating Safety-First Constraints in Linear Programming Production Models." *Western Journal of Agricultural Economics* 13, no. 1 (1988): 29-36.

Hatch, V., and J. Atwood. "A Risk Programming Model for Farm-Raised Catfish." *Aquaculture* 70 (1988): 219-30.

Atwood, J., M.J. Watts, and G.A. Helmers. "Chance-Constrained Financing as a Response to Financial Risk." *American Journal of Agricultural Economics* 70, no. 1 (1988): 79-89.

Atwood, J., L.J. Held, G.A. Helmers, and M.J. Watts. "Performance of Risk-Income Models Outside the Original Data Set." *Southern Journal of Agricultural Economics* 18, no. 2 (1986): 113-23.

Helmers, G.A., M.R. Langemeier, and J. Atwood. "An Economic Analysis of Alternative Cropping Systems for East Central Nebraska." *American Journal of Alternative Agriculture* 1, no. 4 (1985): 153-58.

Helmers, G.A., M.J. Watts, and J. Atwood. "Relevancy of Cash Flow as a Measure of Business Performance." *Agribusiness: An International Journal* 1, no. 4 (1985): 311-31.

Atwood, J. "Demonstration of the Use of Lower Partial Moments to Improve Safety-First Probability Limits." *American Journal of Agricultural Economics* 67, no. 4 (1985): 787-93.

Helmers, G.A., R.V. Sahs, and J. Atwood. "Risk-Income Efficient Leases - The Landlord's Perspective." *Journal of the American Society of Farm Managers and Rural Appraisers* 49, no. 2 (1985): 27-33.

Helmers, G.A., L.J. Held, M.J. Watts, and J. Atwood. "Deviation Constrained Programming: The Impact of Risk Income Frontiers." *North Central Journal of Agricultural Economics* 6 (1984): 142-50.

Reviewed Publications:

Brester, G.W., J.M. Marsh, and J. Atwood. "Who Will Bear the Costs of Country-of-Origin Labeling?" *Choices* 19, 4 (Fourth Quarter 2004).

Book Chapters (Reviewed):

Atwood, J., M. Watts, V. Smith, G. Helmers, and B. Brava Ureta. "Implications of Tax Policy for Farm Structure." *The Changing Size and Structure of America's Farms*, Westview Press, 1993.

Journal Manuscripts Under Review:

Shaik, S., J.A. Atwood and S. Bhattacharjee. 2012. "Hierarchical Linear Model to Examine Normality of Corn Crop Yield Residuals", *Journal of Agricultural and Resource Economics*. (under revision)

Watts, M., J. A. Atwood, and B. Beattie. "Environmental Policy Implications when Whole-Farm Irrigation Water is Fixed." *Journal of Agricultural and Resource Economics*.

Working Papers and Manuscripts in Preparation:

Atwood, J. "Cash Flow vs. Collateral Based Lending: Is There a More Informative Middle 'C'?"

Atwood, J., A. Bittenger, and V. Smith. "Developing Consistent Marginal Effect Estimates in a Simultaneous Equation Model with Limited Dependent Variables." To be submitted to *International Economic Review*. February , 2013.

Invited Papers:

Atwood, J. "Using R for Agent Based Modeling." Canadian and Western Agricultural Associations Joint Annual Meetings. Banff, Alberta. June, 2011.

Atwood, J. "Cash Flow vs. Collateral Based Lending: Is There a More Informative Middle 'C'?". University of Illinois - ACE Departmental Seminar Series. September 25, 2009

Atwood, J. "A Brief Overview of Weather Derivatives and the Effects of Potential Trends upon Temperature Based Derivatives " SCC-76 Economics and Management of Risk in Agriculture and Natural Resources Meetings, Galveston, TX, March 19-21, 2009.

Atwood, J., and D.Buschena. " An Overview of Copulas and Other Recent Developments in Modeling Joint Distributions with "Unrelated" Marginal Distributions and Asymmetric Upside and Downside Joint Relationships." SCC-76 Economics and Management of Risk in Agriculture and Natural Resources Meetings, Orange City, AL, March 15-17, 2007.

Atwood, J., and M.J. Watts. "Using Satellite-Based and/or Weather Station Information to Construct Smaller than County Sized Area Insurance Instruments." SCC-76 Economics and Management of Risk in Agriculture and Natural Resources Meetings, Myrtle Beach, SC, March 16-18, 2006.

Atwood, J., and J. Robison-Cox. "Fraud Detection in Federal Crop Insurance." Annual meeting of group *IEG-76 Economics and Management in Agriculture and Natural Resources* Gulf Shores, Alabama. March 25-27, 2004.

Atwood, J., and D.E. Buschena. "An Analysis of Risk Attitudes over Income." *American Agricultural Economics Association Meetings*, Toronto, Canada, 1997.

Atwood, J., and D.E. Buschena. "An Analysis of Risk Attitudes over Income." *Southern Regional Project Meetings*, Gulf Shores, Alabama, March 1996.

Atwood, J., and M.J. Watts. "Bootstrapping for Risk Estimation When Setting Premiums on Crop Insurance." *Statistics Research Seminar*, Department of Statistics, Montana State University, November 1994.

Atwood, J., and M.J. Watts. "Bootstrapping Discrete Markovian Transition Probabilities with Complete and Reduced Sets of State Variables." Published in *Quantifying Long Run Agricultural Risks and Evaluating Farmer Responses to Risk. Proceedings of a Seminar sponsored by Southern Regional Project S-232*. Department of Resource Economics and Policy, University of Maine, Orono, Maine, June 1993.

Helmers, G.A., J. Atwood, and T. Jaued. "Modeling Irrigation Decisions and Stream Flow Minimums - An Application of Discrete Stochastic Programming and Zero-One Safety First Programming." Published in *Quantifying Long Run Agricultural Risks and Evaluating Farmer Responses to Risk. Proceedings of a Seminar sponsored by Southern Regional Project S-232*. Department of Resource Economics and Policy, University of Maine, Orono, Maine, June 1993.

Atwood, J. "The Evaluation of Probability Distributions with Special Emphasis on Price Distributions Derived from Option Premiums: A Discussion." Published in *Future Directions in Risk Analysis for Agricultural Production Firms. Proceedings of a Seminar Sponsored by Southern Regional Project S180*. Department of Agricultural and Applied Economics, University of Minnesota, St. Paul, MN, August 1987.

Atwood, J., and G.A. Helmers. "Risk-Return Analysis with Riskiness Evaluated Relative to a Hierarchy of Target Incomes." Paper presented at the annual meeting of the Nebraska Academy of Sciences, Lincoln, NE, April 1985.

Peer Reviewed Competitively Selected Papers:

Helmers, Glenn, Saleem Shaik and Joseph Atwood. "Impact of the Section 1031 Like-Kind Tax Provision on Agricultural Land Values." Selected paper presented at the 2008 Annual Meeting of the *WAEA*, Big Sky, Montana June 25-27, 2008.

Shaik, S., J. Atwood, and G. Helmers. "Farm Programs and Agriculture Land Value: Case of Southern Agriculture." Selected Paper, SAEA Annual Meeting, Orlando, Florida, February 5-8, 2006.

Atwood, J., and J. Kastens. "Spatial Analysis in Crop Insurance." Selected paper, WAEA Annual Meeting, San Francisco, CA, July 6-8, 2005.

Shaik, S., and J. Atwood. "Spatial Analysis in Federal Crop Insurance: Challenges and Opportunities." Selected paper, AAEA Annual Meeting, Providence, Rhode Island, July 24-27, 2005.

Shaik, S., and J. Atwood. "Spatial Analysis in Federal Crop Insurance: Challenges." Selected paper, WAEA Annual Meeting, San Francisco, CA, July 6-8, 2005.

Shaik, S., J. Atwood, and G. Helmers. "The Evolution of Farm Programs and their Contribution to Farm Size." Selected Paper, AAEA Annual Meeting, Providence, Rhode Island, July 24-27, 2005.

Atwood, J., J. Robison-Cox, and S. Shaik. "A Statistical Examination of 'Yield Switching' Fraud in the Federal Crop Insurance Program." Selected Paper, AAEA Annual Meeting, Denver, Colorado, August 1-4, 2004.

Shaik, S., and J. Atwood. "Demand for Optional Units in Crop Insurance." Selected Paper, AAEA Annual Meeting, Montreal, Quebec, July 27-30, 2003.

Shaik, S., G.A. Helmers, and J. Atwood. "Scope and Scale Efficiency Gains due to Vertical Integration in the U.S. Hog Sector." Selected Paper, SAEA Annual Meetings, Mobile, Alabama, February 1-5, 2003.

Helmers, G.A., and J. Atwood. "Causes for Convexity in Remaining Value Functions." Proc. S.E. Dec. Sci. Inst. 2002, pp. 28-30.

Atwood, J., G.A. Helmers, and S. Shaik. "Farm and Nonfarm Factors Influencing Farm Size." Selected paper, Western & Am. Agr. Econ. Assn. Mtgs., Long Beach, Calif., July 28-31, 2002.

Shaik S., and Atwood, J. "Optional Unit Policy in Crop Insurance." Selected paper, Western & Am. Agr. Econ. Assn. Mtgs., Long Beach, Calif., July 28-31, 2002.

Shaik S., and Atwood, J. "An Examination of Types of Adverse Selection in Federal Crop Insurance." Selected paper, Western & Am. Agr. Econ. Assn. Mtgs., Long Beach, Calif., July 28-31, 2002.

Helmers, G.A., J. Atwood, and S. Shaik. "Fertilizer and Fertilizer-Crop Diversification." Selected paper, W. Agr. Econ. Assn. Annual Mtgs., Logan, Utah, July 8-11, 2001.

Helmers, G.A., J. Atwood, and M. Watts. "Educational Opportunities Using Economic Depreciation." Proc. SE Dec. Sci. Inst., 2001, pp. 45-47.

Shaik, S., and J. Atwood. "An Examination of the Effects of Crop Insurance on the Resource use and Production Mix: County level Analysis." Am. Agr. Econ. Assn., Chicago, IL, August 2001.

Shaik, S., and J. Atwood. "Estimating the Demand of Insurance and Supply of Indemnity Payments in Crop Insurance." Presented at the annual meetings of the Am. Agr. Econ. Assn., Tampa, FL, Jul. 30-Aug. 2, 2000.

Atwood, J., S. Shaik, G.A. Helmers, and M. Langemeier. "Impact of Nitrogen Reductions on Risk and Net Returns." Selected paper, S. Agr. Econ. Assn. meetings, Memphis, TN, Jan. 30 - Feb. 3, 1999.

Shaik, S., G.A. Helmers, and J. Atwood. "Farm-Nonfarm Relationships Affecting Farm Size in the Southeast." Selected paper, S. Agr. Econ. Assn. meetings, Memphis, TN, Jan. 30 - Feb. 3, 1999.

Helmers, G.A., W. Dias, M.R. Langemeier, and J. Atwood. "Risk Analysis of Cropping Systems using Experimental Cropping System-Fertilizer Data." Selected paper, Am. Agr. Econ. Assn. meetings, Salt Lake City, UT, August 2-5, 1998.

Helmers, G.A., and J. Atwood. "Endogenizing Durable Asset Ownership Costs in Linear Programming Models." Proceedings Southeast Decision Science Institute meetings, VA, February 25-27, 1998:33-35.

Atwood, J., and G.A. Helmers. "Effect of Machine-Labor Fixity on Optimum Cropping Decisions." Selected paper, S. Agr. Econ. Assn. meetings, Little Rock, AR, February 1-4, 1998.

Selly, R.A., G.A. Helmers, and J. Atwood. "Accuracy of a Simplified Procedure of Generating Long-Term Costs in Crop Budgets." Selected paper, S. Agr. Econ. Assn. meetings, Little Rock, AR, February 1-4, 1998.

Atwood, J., G.A. Helmers, and K. Bernhardt. "Estimates of Long-Run Multi Cropping Efficiencies for Alternative Crops." Selected paper, W. Agr. Econ. Assn. meetings, Sparks, NV, Jul. 13-17, 1997. *Journal Agriculture and Application Economics* 22(1997): 401.

Helmers, G.A., and J. Atwood. "Estimates of Capital-Labor Substitution Derived from a Farm Firm Programming Model." Selected paper, S. Agr. Econ. Assn. meeting, Birmingham, AL, February 2-5, 1997. *Journal Agriculture and Application Economics* 29(1997): 201.

Atwood, J., and G.A. Helmers. "Estimates of Bias and Improvements in Short-Run Programming Models for Cropping System Analysis." Selected paper, S. Agr. Econ. Assn. meetings, Birmingham, AL, February 2-5, 1997. *Journal of Agriculture and Application Economics* 29(1997): 197.

Javed, M.T., G.A. Helmers, J. Atwood, and M. Baker. "Optimum Crop and Irrigation Decisions Under Uncertainty in Water Availability." Selected abstract, S. Agr. Econ. Assn. meetings, Greensboro, North Carolina, February 4-7, 1996. *Journal Agriculture and Application Economics* 28(1996): 226

Helmers, G.A. and J. Atwood. "Crop Diversification-Multi Cropping vs. Multi Herbicide-Tillage Methods." Selected paper, Am. Agr. Econ. Assn. meetings, San Antonio, Texas, July 28-31, 1996.

Helmers, G.A., J. Atwood, and K. Bernhardt. "Impact of the 1990 Flexible Acreage and Reduced Program Acreage Base Provisions on Program Base and Net Returns to Producers." Selected paper, S. Agri. Econ. Assn. meetings, New Orleans, Louisiana, Jan. 29 - Feb. 1, 1995.

Helmers, G.A., J. Atwood, T. Javed, and M. Baker. "The Performance of a Discrete Stochastic Programming Model with Chance Constraints on Environmentally Sensitive Stream Flow." Proceedings of the Southeast Decision Sciences Institute, 1995, pp. 42-44.

Javed, T., G.A. Helmers, J. Atwood, and M. Baker. "Impacts of Reducing Remaining Stream Flow Variability on Irrigation Returns and Reservoir Levels." Paper presented to American Water Resources Association Spring Symposium, Salt Lake City, Utah, April 23-26, 1995. Proceedings, American Water Resources Association Spring Symposium, p. 189.

Helmers, G.A., T. Javed, M. Baker, and J. Atwood. "Effects of Reducing Variability in Reservoir Water Levels on Irrigation Returns and Remaining Stream Flow Variability." Selected poster, S. Agri. Econ. Assn. meetings, New Orleans, Louisiana, Jan. 29 - Feb. 1, 1995.

Atwood, J., S. Saleem, and G.A. Helmers. "Farm Size Adjustments and the Non Farm Economy - An Extension of the Kislev-Peterson Hypothesis." Selected paper, Am. Agr. Econ. Assn. meetings, Indianapolis, Indiana, Aug. 6-9, 1995.

Helmers, G.A., and J. Atwood. "Implicit Bias of Commodity Programs by Farm Size." Selected paper, Am. Agr. Econ. Assn. meetings, Indianapolis, Indiana, August 6-9, 1995.

Helmers, G.A., S.L. Elmore, J. Atwood, and K.J. Bernhardt. "Estimating Biases Toward Sustainable Agriculture from Crop Base Programs." Selected paper, W. Agri. Econ. Assn. meetings, Rapid City, South Dakota, July 9-12, 1995.

Helmers, G.A., J. Atwood, K. Bernhardt. "Reduced-Cost Benefits from Multiple-Crop Systems." Selected paper presented at Am. Agr. Econ. Assn. meetings, San Diego, California, August 7-10, 1994.

Javed, M.T., G.A. Helmers, J. Atwood, and M. Baker. "The Effect of Conditional vs. Unconditional Probabilities in a Discrete Stochastic Programming Model of Irrigation Decisions." Selected paper, S. Agri. Econ. Assn. meetings, Nashville, Tennessee, February 5-9, 1994.

Helmers, G.A., K. J. Bernhardt, and J. Atwood. "Impacts of Commodity Programs on Sustainable Agriculture." Paper presented at the annual meetings of the W. Agri. Econ. Assn., Edmonton, Canada, July 1993.

Helmers, G.A., K.J. Bernhardt, and J. Atwood. "Base Building Incentives and the Food, Agriculture, Conservation and Trade Act of 1990." Paper presented at the annual meetings of the Am. Agr. Econ. Assn., Orlando, Florida, August 1993.

Atwood, J., V.H. Smith, and M.J. Watts. "Lemons, List Prices and Other Problems with Measuring Economic Depreciation Rates for Agricultural Machinery." Proceedings of the annual meetings of the W. Agri. Econ. Assn., Portland, Oregon, August 1991.

Goroski, J., V. Smith, J. Atwood, and M.J. Watts. "Economic Depreciation and Tax Policy: The Case of Combine Harvesters." Paper presented at the annual meetings of the Am. Agri. Econ. Assn., Vancouver, BC, Canada, August 1990

Watts, M.J., J. Atwood, G.A. Helmers, and L.J. Held. "Safety - First Programming - A Zero-One Approach." Paper presented at the annual meetings of the Am. Agr. Econ. Assn., Baton Rouge, Louisiana, August 1989.

Held, L.J., G.A. Helmers, J. Atwood, and M.J. Watts. "Effect of Machinery Cost Economics of Diversified Risk Efficient Crop Plans." Paper presented at the W. Agri. Econ. Assn. meetings, Manhattan, Kansas, July 1987.

Helmers, G.A., J. Atwood, M.J. Watts, and L.J. Held. "Financial Performance of Risk-Income Models." Paper presented at the W. Agri. Econ. Assn. meetings, Manhattan, Kansas, July 1987.

Hatch, V., J. Atwood, and J. Seger. "An Application of Safety-First Probability Limits in a Discrete Stochastic Farm Management Programming Model." Paper presented at the S. Agri. Econ. Assn. meetings, Nashville, Tennessee, February 1987.

Atwood, J., and K. McCurdy. "Bid and Sell Prices for Assets: An Application of Vector Sensitivity Analysis in Linear Programming." Paper presented at the S. Agri. Econ. Assn. meetings, Nashville, Tennessee, February 1987.

Atwood, J., G.A. Helmers, K.M. Eskridge, J.M. Morrill, and M.R. Langemeier. "Pooling Cross-Sectional and Time-Series Yield Data for Risk Analysis." Paper presented at the annual meetings of Am. Agri. Econ. Assn., Reno, Nevada, July 1986.

Held, L.J., G.A. Helmers, J. Atwood, and M.J. Watts. "Impact of Business Versus Financial Risk on Risk Income Choices." Paper presented at the annual meetings of Am. Agri. Econ. Assn., Reno, Nevada, July 1986.

Atwood, J., D.D. Schulte, and G.A. Helmers. "Systems Analysis of Economics of On-Farm Energy Production." Paper presented at the annual meeting of American Society of Agricultural Engineers, San Luis Obispo, California, June 1986.

Helmers, G.A., J. Atwood, and R.J. Sahs. "Landlord-Tenant Lease Efficiency - A Risk Income Analysis." Presented at the annual meetings of the S. Agri. Econ. Assn., Orlando, Florida, February 1986.

Helmers, G.A., J. Atwood, M.R. Langemeier, and B.B. Johnson. "Sub-Optimal Analysis of Organic Farming in a Multiobjective Setting." Presented at the annual meetings of the Am. Agri. Econ. Assn., Ames, Iowa, August 1985.

Atwood, J., M.J. Watts, and G.A. Helmers. "Reduction of the Second Degree Stochastically Efficient Set Using Safety First Type Constraints." Presented at the annual meetings of the W. Agri. Econ. Assn., Saskatoon, Saskatchewan, Canada, July 1985.

Atwood, J., M.J. Watts, L.J. Held, and G.A. Helmers. "Imposing Safety-First Constraints on a MOTAD Frontier." Presented at the annual meetings of the W. Agri. Econ. Assn., San Diego, CA, July 1984.

Atwood, J., G.A. Helmers, and N.A. Stanley. "Modeling the Impact of Financial Growth on Farm Risk Behavior across Tim." Presented at the Southern Agricultural Economics Association meetings, Nashville, Tennessee, February 1984. (Abstract: *Southern Journal of Agricultural Economics* 16(1): 191).

Atwood, J., and G.A. Helmers. "After-Tax Implications of Graduated Payment Mortgages at the Micro-Level-Housing Example." Presented at the annual meeting of the Nebraska Economics and Business Association, Lincoln, Nebraska, October 1983.

Helmers, G.A., and J. Atwood. "The Impact of Inflation on Optimum Investment Strategy and Equity Position of Firms." Presented at the annual meeting of the Nebraska Economics and Business Association, Kearney, Nebraska, October 1982.

Published Symposium or Proceedings Papers:

Helmers, G.A., J. Atwood, M.J. Watts, and L.J. Held. "Fixity and Capital Costing Assumptions in Agricultural Risk Research with Implications to Livestock." Paper presented at the S-180 Regional Meeting, Tampa, FL, March 1986.

Held, L.J., and J. Atwood. "Evaluating the Performance of Risk Programming Models Outside the Data Set." Paper presented at the GPC-10 Meeting, Fargo, ND, May 1985.

Atwood, J., M.J. Watts, and G.A. Helmers. "Safety-First Models Based on Lower Partial Moment Sample Statistics." Paper presented at the S-180 Regional Meeting, Charleston, SC, March 1985.

Helmers, G.A. and J. Atwood. "Kinds and Sources of Risks in Livestock Production and Marketing." In: *Risk Management Strategies for Agricultural Production Firms: Perspectives and Research Issues*. Oklahoma Agricultural Experiment Station, Department of Agricultural Economics, AE-8350, 1983.

Departmental Publications for Professional and Public Distribution:

Atwood. J. "An Examination of LR 93 Economic Research Issues." Report prepared for the Nebraska Legislature. December, 2007.

Zhen, C., J. Atwood, and D. Buschena. "Improving Statistical Models of Crop Yield Forecasting Using AVHRR-NDVI Satellite Data." Staff Paper No. 2004-3. Department of Agricultural Economics and Economics, Montana State University, December 2004.

Atwood, J., J. Robison-Cox, and S. Shaik. "A Direct Test of 'Yield Switching' Fraud in the Federal Crop Insurance Program." Staff Paper 2003-2. Department of Agricultural Economics and Economics, Montana State University, June 2003.

Atwood, J., M.J. Watts, and S. Shaik." An Examination of Potential Fraud in Crop Insurance Due to Yield Switching between Optional Units in US Cotton". Staff Paper #2003-1. Department of Agricultural Economics and Economics, Montana State University, January 2003.

Atwood, J., and M.J. Watts. "Rating Avocado Insurance: An Overview." Staff Paper 2000-6. Department of Agricultural Economics and Economics, Montana State University, January 2000.

Watts, M.J., J. Atwood, and S. Shaik. "Low Risk Farmer." Staff Paper 2000-5. Department of Agricultural Economics and Economics, Montana State University, January 2000.

Atwood, J., and J. Saltiel. "Heteroskedasticity of Farm Level Residual Variability." Staff Paper 2000-2. Department of Agricultural Economics and Economics, Montana State University, January 2000.

Atwood, J., S. Shaik, and M.J. Watts. "Are Crop Yields Really Normally Distributed?" Staff Paper 1999a-3. Department of Agricultural Economics and Economics, Montana State University, December 1999.

Atwood, J., and S. Shaik. "Measurement of Adverse Selection in Crop Insurance Using an Expected Indemnity Approach." Staff Paper 1999a-2. Department of Agricultural Economics and Economics, Montana State University, December 1999.

Atwood, J., G.A. Helmers, and S. Shaik. "Examining the Effects of Rural Economies on Farm Size and Off-Farm Employment." Staff Paper 1999a-1. Department of Agricultural Economics and Economics, Montana State University, July 1999.

Atwood, J., and M.J. Watts. "Crop Insurance Update and Discussion." Staff Paper 1999a-6. Department of Agricultural Economics and Economics, Montana State University, June 1999.

Atwood, J., J. Driscoll, V. Smith, and M.J. Watts. "Federal Crop Insurance Programs - History, Practice, and Issues." Staff Paper 1999a-4. Montana State University. Department of Agricultural Economics and Economics. May 1999.

Atwood, J., and M.J. Watts. "Federal Crop Insurance Programs and Cotton Briefing Information." Staff Paper 1999a-5. Department of Agricultural Economics and Economics, Montana State University, May 1999.

Atwood, J., A.B. Baquet, and M.J. Watts. "Income Protection." Staff Paper 1997-9. Department of Agricultural Economics and Economics, Montana State University, 1997

Atwood, J. and G.A. Helmers. "Examining Quantity and Quality Effects of Restricting Nitrogen Application to Feedgrains: A Partial Equilibria Analysis." Staff Paper 1996-1. Department of Agricultural Economics and Economics, Montana State University, 1996

Atwood, J., V.H. Smith, and M.J. Watts. "Economic Depreciation and Tax Policy: The Case of Combine Harvesters and Semi-Trailer Cabs." Staff Paper 1992-8. Department of Agricultural Economics and Economics, Montana State University, 1992

Watts, M.J., A. Baquet, and J. Atwood. "Interest Rate Risk Premiums and Credit Availability." Staff Paper 1992-7. Department of Agricultural Economics and Economics, Montana State University, 1992

Smith, V.H., U.R. Kehoe, M. Cremer, and J. Atwood. "The Widow's Nite: Altruism, Self-Interest, and Voluntary Giving." Staff Paper 1992-6. Department of Agricultural Economics and Economics, Montana State University, 1992.

Goetting, M.A., J. Atwood, and D. Young. "Estimating the Amount to Save for College." Montguide #MT199103HR. Montana State University Extension Service, 1990.

Goetting, M.A., J. Atwood, and P.M. Tengel. "Estimating the Amount to Save for Retirement." Montguide #MT8905. Montana State University Extension Service, 1989

Helmers, G.A., J. Atwood, and M.R. Langemeier. "Economics of Alternative Crop Rotation Systems for East-Central Nebraska - A Preliminary Analysis." Staff Paper #14. Department of Agricultural Economics, University of Nebraska, 1984.

Helmers, G.A., M.J. Watts, and J. Atwood. "Relevancy of Cash Flow as a Measure of Business Performance." Staff Paper #5. Department of Agricultural Economics, University of Nebraska. 1984

Atwood, J., and L.K. Fischer. "Cost of Production of Fuel Ethanol in Farm-Size Plants." Report #115. Department of Agricultural Economics, University of Nebraska, 1980

Turner, M.S., and J. Atwood. "Trucking Grain? What Does It Cost?" Report #94. Department of Agricultural Economics, University of Nebraska, 1979

Unpublished Papers:

Helmers, G.A., M.J. Watts, and J. Atwood. "Asset Fixity and Farm Management Analysis." Presented at the GPC-10 Meetings, Fort Collins, CO, May 1986.

Helmers, G.A., and J. Atwood. "Agricultural Risk Research - Its Development and Emerging Thrusts." Presented at the NCR-113 Meetings, St. Louis, MO, October 1984.

Atwood, J., and G.A. Helmers. "Structural Implications of Tax Timing with Constant Real Versus Constant Nominal Debt Payments." Presented at the GPC-10 Meetings, Bozeman, MT, June 1983

Other Presentations:

Atwood, J. "Cash Flow vs. Collateral Based Lending: Is There a More Informative Middle 'C'?". Department of Agricultural Economics and Economics Seminar. Montana State University. November, 2009.

Atwood, J. "Weather Derivatives: An Overview and Examination of Issues in the Development of the Weather Derivatives Market." Department of Agricultural Economics and Economics Seminar. Montana State University. December, 2008.

Atwood, J. "Weather Derivatives: An Overview and Examination of Issues in the Development of the Weather Derivatives Market." Department of Agricultural Economics Seminar Series. University of Nebraska-Lincoln. April, 2008.

Atwood, J. "The Use of Copulas in Modeling Joint Distributions." Department of Statistics Seminar Series, University of Nebraska-Lincoln, November, 2007.

Atwood, J. "An Overview of Copulas in Modeling Joint Distributions." Department of Mathematical Sciences Seminar Series, Montana State University, April, 2007.

Atwood, J. "Information Content in Lagrangian Augmented Systems: An Application to Fraud Detection in Federal Crop Insurance." Department of Mathematical Sciences Seminar Series, Montana State University, October 2003.

Atwood, J. "A Direct Test of 'Yield Switching, Fraud in the Federal Crop Insurance Program." Department of Agricultural Economics and Economics Seminar Series, University of Nebraska, April 2003.

Atwood, J., and M.J. Watts. "Are Credit Card Interest Rates Too High?" Seminar Department of Agricultural Economics Seminar Series, University of Nebraska, July 1992.

Smith, V., J. Atwood, and M.J. Watts. "Economic Depreciation and Tax Policy in the United States." Presented as an Invited Paper for a University of Nottingham (England) Economics faculty seminar by V. Smith, December 1991.

Smith, V., J. Atwood, and M.J. Watts. "Economic Depreciation and Tax Policy in the United States." Presented as an Invited Seminar for a University of Manchester (England) Agricultural Economics faculty seminar by V. Smith, December 1991.

Smith, V., J. Atwood, and M.J. Watts. "Economic Depreciation and Tax Policy." Presented as an Invited Paper to a USDA Economic Research Service meeting, Washington, D.C. by V. Smith, September 1991.

Atwood, J. "Risk Modeling Using Lower Partial Moments." Invited Speaker Seminar Series, Department of Agricultural Economics, University of Georgia, Athens, GA, January 1986.

Atwood, J., and G. Helmers. "Cash-Flow - Relevance to Agriculture in the 1980's." Presented to the Executive Committee of the Nebraska Banker's Association, Lincoln, NE, May 1984.

Atwood, J. "Costs of Producing Fuel Ethanol in On-Farm Plants." Invited presentation at annual meeting of the Great Plains Resource and Economics Committee, Big Sky, MT, June 1980.

Atwood, J. "Costs of Producing Fuel Ethanol in On-Farm Plants." Invited presentation at Four State Conference for Farm Management Specialists, Wagonner, OK, May 1980.

HONORS AND AWARDS:

Pure Gold Award. Montana State University. 2011
Distinguished Visiting Professor. University of Nebraska. 2007-2008
Friend of the Student Award. College of Agriculture, Montana State University, 2003.
Outstanding Published Research Award. Western Agricultural Economics Association, 1999.
Who's Who Among America's Teachers, 1997-98
Alpha Zeta, College of Agriculture, Teacher of the Semester, Fall 1991

University of Nebraska, Lincoln:
Department of Agricultural Economics Outstanding Ph.D. Student Award, 1984
Department of Agricultural Economics Outstanding Master's Student, 1980
President, Ag Economics Graduate Student Association, 1978-1979
Gamma Sigma Delta Outstanding Senior Award, 1978
Animal Science Department Senior Scholarship Award, 1978

Lubbock Christian College, Lubbock, Texas:

Junior Class Achievement Award - 4.0 Cumulative GPA, 1977
ACRS - Lubbock Chapter Merit Scholarship, 1977
Alpha Chi Honor Society, 1976-1977
Outstanding Transfer Student Scholarship, 1976

York College, York, Nebraska:

Highest GPA in Graduating Class, 1976
Who's Who in American Junior Colleges, 1976
Sophomore Class President, 1976
Phi Beta Kappa, 1976
Bible Honors Student, 1976
Outstanding Sociology Student, 1976
Outstanding English Student, 1976

PROFESSIONAL AND UNIVERSITY SERVICE:

Associate Editor - *JARE* 2009-2011
Departmental Search Committee for three positions, 2008-2010.
College of Agriculture Recruitment and Retention Committee, 2006, 2007.
Department Advisory-Promotion Tenure Committee, 1990-1992, 1995-1996, 1998-1999, 2000-2002, 2010-2011.
Department Graduate Committee, 2005-2011.
Chairman, College of Agriculture Computer Policy and Oversight Committee, 1995, 1996, 1997.
Chair, Department Search Committee - two positions, 1997.
Montana State University Promotion and Tenure Committee, 1997.
Montana State University Search Committee for Dean of Agriculture, 1998-1999.
Advisory Council, Western Agricultural Economics Association, 1994-1997.
MSU Computing Service, Software Advisory Committee 1991-1997.
University Computer Policy Committee, 1990-1997.
University Research Computing Committee, 1990-1994, 1996.
Advisor to Alpha Zeta, 1990-1993.
Departmental Search Committee for four positions, 1990-1992.
Coordinated Poster Selection/Review Process--Farm Management-Risk Area for meetings of American Agricultural Economics Association Meetings, 1990, 2006-2008.
AERO-MSU Joint Planning Committee on Sustainable Agriculture, Winter 1988-1989.
Departmental Curricula Committee for Montana Extension Agent Training, Winter 1988-1989.
Chaired Selected Papers Session, Annual Meetings of the American Agricultural Association, August 1988.
Search Committee for five positions in College of Business, Fall 1988.
Chaired Selected Papers Session, Annual Meetings of the SAEA, February 1986.
Reviewed manuscripts for *American Journal of Agricultural Economics, Western Journal of Agricultural Economics, Journal of Agricultural and Resource Economics, Review of Agricultural Economics, J.E.E.M., Canadian Journal of Agricultural Economics, Southern Journal of Agricultural Economics,* 1985-2008.
Advisor for 12 to 26 undergraduate students annually 1988-Present.
Chaired or served on 32 Masters and Ph.D. committees at Auburn University, UNL, and MSU.

PROFESSIONAL MEMBERSHIPS:

American Agricultural Economics Association
American Risk and Insurance Association
Southern Agricultural Economics Association
Western Agricultural Economics Association

GRANT AND CONTRACT SUPPORT:

USDA/RMA, "Holistic Debt, Crop Insurance, and Whole Farm Financial Risk Management Tool." $306,835; 1/2005-7/2009. (With Tim Watts)

USDA/RMA, "Avocado Rating Instruments Contract." $10,000; 7/2004-6/2005. (With Myles Watts)

USDA/CSREES, "Investigation of Alternative U.S. Cotton Insurance Product and Rating Procedures." $92,000; 1/2/2001 – 12/31/2001. (With Myles Watts)

USDA/CSREES, "Investigation of Alternative U.S. Crop Insurance Product and Rating Procedures." $43,000; 7/1/2001 – 12/31/2001. (With Myles Watts)

USDA-ERS, "Assessing the Feasibility of Implementing IP on a Broad Basis." $203,140; 1999-2001. (With Myles Watts)

USDA-ERS, "Review of US Cotton Rates." $69,000; 1998-2001. (With Myles Watts).

USDA-ERS, "Compliance and Fraud Detection." $200,000; 1999-2000. (With Myles Watts and IITRI Corp.)

USDA-ERS, "Expansion of Avocado Insurance Program." $70,451; 1999-2000. (With Myles Watts)

USDA-ERS, "Effects of Unit Size on Premiums Paid." $167,000; 1999-2000. (With Myles Watts)

USDA-ERS, "Expansion of Income Protection Insurance." $80,000; 1996-1998. (With Myles Watts)

USDA-ERS, "Developing an Avocado Revenue Insurance Product." $34,860; 1996-1998. (With Myles Watts)

USDA-ERS, "Cost of Production-Based Revenue Insurance: A Pilot Project." $99,334; 1995-1996. (With Myles Watts)

USDA-ERS, "A Combined Crop Approach to Whole Farm Insurance: Development of a Pilot Program." $96,831; 1995. (With Myles Watts)

Federal Crop Insurance Corporation, "Whole Farm Insurance." $34,500; 1993-1995. (With Myles Watts)

Montana Wheat and Barley Committee, "The Impact of Group Risk Plan Crop Insurance on Montana Producers." $18,000; 1993-1994. (With Myles Watts and Alan Baquet)

Federal Crop Insurance Corp., "An Investigation of Multiple Peril Crop Insurance Participation Rates in Semi-Arid Production Regions: The Role of Rate Structures, Disaster Relief, and Other Commodity Programs." $110,000; 1992-1994. (With Myles Watts and Alan Baquet)

MONTS, "Economic Depreciation: The Constant Rate Hypothesis and Tax Policy." $10,500; 1990-1991.

Alabama Research Institute, "Technology for Beef Cattle Production and Marketing." $125,000; 1986-1987. (With Rob Martin)

Alabama Peanut Producers, "Developing Production Practices for Peanuts That Will Maintain Yields While Reducing Production Costs." $5,000; 1986-1987. (With Rob Martin)

Center for Rural Affairs, Walthill, Nebraska, "Tax Incentives on Sandhill Land Development." $4,000; 1983-1984. (With Glenn Helmers)

UNPUBLISHED RESULTS FROM FUNDED RESEARCH:

- Numerous Internal Reports to RMA-USDA, U.S. Congress, and Other Entities. (Not authorized for public release.)

- Development and Modification of Insurance Rating Methodology for RMA-USDA
  - Developed orthogonal decomposition methods to incorporate information from disparate sources and over different time intervals into premium rates. (Adopted in pilot areas/crops and under consideration by RMA.)
  - Developed statistical indexing procedures that improve efficiency of crop insurance liability establishment procedures. (Adopted in pilot areas/crops and under consideration by RMA for expanded adoption.)
  - Developed spatial statistical catastrophic loading/smoothing procedures. (Adopted in pilot areas/crops and under consideration by RMA for expanded adoption.)
  - Developed several crop insurance products currently offered by RMA-USDA.
  - Procedures adapted or under consideration by private insurance and reinsurance entities.

- Identification of Potential Waste, Fraud, and Abuse
  - Developed statistical procedures (with corresponding computer code) to screen all U.S. purchasers of crop insurance for potential yield switching fraud. RMA-USDA has applied procedure and code to all crop insurees.
  - Identified potential waste, fraud, and abuse of provisions of RMA crop insurance products. Recommended corrective actions. RMA-USDA has implemented some recommendations and is considering others.

Timothy W. T. Fitzgerald
Department of Agricultural Economics & Economics
Box 172920 Bozeman, MT 59717-2920
(406) 994-5619
timothy.fitzgerald@montana.edu
http://www.montana.edu/timfitz

EDUCATION

Ph.D. in Agricultural and Resource Economics
University of Maryland, January 2009
Dissertation Title: *Essays on Split Estates in Energy Development*
A.B. *summa cum laude* in Economics and Environmental Studies
Bowdoin College, May 1997

ACADEMIC EMPLOYMENT

Assistant Professor
Agricultural Economics & Economics, Montana State University
January 2009–present
Adjunct Instructor
Agricultural Economics & Economics, Montana State University
August-December 2007–2008

HONORS AND AWARDS

John V. Krutilla Research Fellow, Resources for the Future, 2012–2013
Meridian Institute Conservation Leadership Partnership Fellow, 2012
Lone Mountain Fellow, PERC, 2012
Noyes Political Economy Prize, Bowdoin College, 1997
Surdna Foundation Undergraduate Research Fellowship, 1996–1997

PUBLICATIONS

Refereed Journals

Fitzgerald, Timothy. 2013. The Role of Ownership in Environmental Performance: Evidence from Coalbed Methane Development. *Environmental Management*. 52(6): 1503–1517.

Banzhaf, H. Spencer, Timothy Fitzgerald, and Kurt Schnier. 2013. Non-Regulatory Approaches to the Environment: Coasean and Pigouvian Perspectives. *Review of Environmental Economics and Policy*. 7(2): 238–258.

Fitzgerald, Timothy. 2012. Natural Resource Production under Divided Ownership: Evidence from Coalbed Methane. *Review of Law and Economics*. 8(3): 719–757.

Fitzgerald, Timothy. 2010. Evaluating Split Estates in Oil and Gas Leasing. *Land Economics*. May. 86(2): 294–312.

Contributed Papers

Fitzgerald, Timothy. 2013. Frackonomics: Some Economics of Hydraulic Fracturing. *Case Western Law Review*. 63(4): 1337–1362.

Fitzgerald, Timothy and A. Myrick Freeman III. 2008. Counting the Wealth of Nature: An Overview of Ecosystem Valuation. in Accounting for Mother Nature. ed. Terry L. Anderson, Laura E. Huggins, and Thomas M. Power. Stanford University Press.

Monographs, Technical Reports, and Other Publications

Fitzgerald, Timothy. 2013. Prior Appropriation and Water Quality. Conservation Leadership Council. Policy Paper 2013-02. Washington, DC. July.

Fitzgerald, Timothy, and Grant Zimmerman. 2013. Agriculture in the Tongue River Basin: Output, Water Quality, and Implications. Agricultural Marketing Policy Center Policy Paper 39. Montana State University. May.

Fitzgerald, Timothy. 2012. Understanding Mineral Rights. *MontGuide 2012-07*. Montana State University Extension.

Fitzgerald, Timothy. 2012. Owning Leased Oil and Gas Minerals. *MontGuide 2012-08*. Montana State University Extension.

Fitzgerald, Timothy. 2012. Oil and Gas Leasing. *MontGuide 2012-09*. Montana State University Extension.

McGowen, Patrick, Jaydeep Chaudhari, Brian Church, Janelle Booth, Timothy Fitzgerald, Daniel Richter, and Robert J. Eger III. 2011. Montana Fuel Tax Refunds: Final Report. Western Transportation Institute.

Fitzgerald, Timothy. 2011. Hydraulic Fracturing in Context: Key Institutional Features of an Evolving Technology. *USAEE Dialogue*. 19(2) September.

Fitzgerald, Tim. 2000. Federal Land Exchanges: Let's End the Barter. *PERC Policy Series* PS-18. PERC: Bozeman, MT.

Working Papers

Measuring the Effects of Natural Gas Pipeline Constraints on Regional Pricing and Market Integration (with Roger Avalos and Randal Rucker)

Effects and Incidence of Exploration and Production Taxes for Oil and Gas

Carbon Offset Use in the EU ETS (with Nathan Braun and Jason Pearcy) *for CESifo volume*

Offset Spread Options in the European Carbon Market *for CESifo volume*

Estimates of U.S. Private Oil and Natural Gas Royalties (with Randal Rucker)

You Can't Drag Them Away: An Economic Analysis of the Wild Horse and Burro Program (with Vanessa Elizondo and Randal Rucker)

Prior Appropriation and Water Quality

Can a Legal Horn Trade Save Rhinos? (with Michael t' Sas-Rolfes)

The Effects of Oil and Gas Fiscal Regimes on Exploration and Production Decisions (with Andrew Stocking)

RECENT PRESENTATIONS

2014 ASSA Annual Meeting, Philadelphia, PA (invited).

2013 ASSA Annual Meeting, San Diego, CA (discussant 2x); Colorado School of Mines, Golden, CO; Columbia University Law School, New York, NY; Big Sky Energy Forum, Billings, MT; AERE Summer Conference, Banff, AB; WAEA Annual Meeting, Monterey, CA; Western Economics Association Annual Conference, Seattle, WA; CESifo Venice Summer Institute, Venice; 32nd USAEE/IAEE Conference, Anchorage, AK; 14th Occasional California Workshop in Environmental and Resource Economics, Santa Barbara, CA.

2012 ASSA Annual Meeting, Chicago, IL; Bowdoin College, Brunswick, ME; University of New Hampshire, Durham, NH; Providing Environmental Services from Agriculture Conference, Washington, DC; WAEA Annual Meeting, Park City, UT; 31st USAEE/IAEE Conference, Austin, TX; Case Western Reserve University Law School, Cleveland, OH; Colorado School of Mines, Golden, CO.

GRANTS

Faculty Excellence Grant, Montana State University, 2013–2014
Faculty Development Award, Montana State University, 2011
Research Enhancement Award, MSU Letters & Sciences, 2009–12
Jacob Goldhaber Travel Grant, University of Maryland, 2007

PROFESSIONAL ACTIVITIES

Affiliations

American Economics Association (AEA), Association of Environmental and Resource Economists (AERE), International Association of Energy Economists (IAEE), Western Agricultural Economics Association (WAEA)

Reviewer

Energy Economics, *Environment & Planning A*, *Environmental Management*, *Journal of Agricultural and Resource Economics*, *Land Economics*, *Natural Resources Research*, *Social Science Journal*

PERSONAL

U.S. Citizen, References available on request.

BIOGRAPHICAL SKETCH

Provide the following information for the key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FOUR PAGES.**

NAME	POSITION TITLE
DAVID W. PASCUAL	**Professor of Immunology**
eRA COMMONS USER NAME	

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, and include postdoctoral training.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	YEAR(s)	FIELD OF STUDY
University of Florida, Gainesville, FL	B.S.	1980	Microbiology
University of Mississippi Medical Center, Jackson, MS	M.S.	1985	Microbiology
University of Mississippi Medical Center, Jackson, MS	Ph.D.	1987	Microbiology
University of Alabama at Birmingham, AL	Postdoc	1987-1990	Neuroimmunology

1977-1980 Undergraduate, University of Florida, Gainesville, FL, B.S., Microbiology
1981-1985 Graduate Student, University of Mississippi Medical Center, Jackson, MS, M.S., Microbiology
1985-1987 Graduate Student, University of Mississippi Medical Center, Jackson, MS, Ph.D., Microbiology
1987-1988 Postdoctoral Fellow, University of Alabama at Birmingham, Birmingham, AL, Department of Physiology & Biophysics
1988-1990 Postdoctoral Fellow, NIH Hypertension Training Grant Fellowship, University of Alabama at Birmingham, Department of Physiology & Biophysics, Birmingham, AL
1990-1992 Research Instructor, Departments of Oral Biology and Microbiology, Univ. of Alabama at Birmingham, Birmingham, AL
1992-1995 Research Assistant Professor of Oral Biology and Immunobiology Vaccine Center, University of Alabama at Birmingham, Birmingham, AL
1995-1998 Assistant Professor of Immunology, Veterinary Molecular Biology, Montana State University, Bozeman, MT
1998-2005 Associate Professor of Immunology, Veterinary Molecular Biology, Montana State University, Bozeman, MT
2001-Present Tenure
2003-Present Affiliate Associate Professor, Department of Immunology, University of Washington, Seattle, WA
2005-2012 Professor of Immunology, Department of Immunology & Infectious Diseases (formerly Veterinary Molecular Biology), Montana State University, Bozeman, MT
2012-present Professor, Department of Infectious Diseases & Pathology, College of Veterinary Medicine, University of Florida, Gainesville, FL

Professional Societies and Honors

1990-Present American Association for the Advancement of Science
1991-Present American Association of Immunologists
1991-Present Society for Mucosal Immunology
1994-Present American Society for Microbiology
1994-Present Fellow, American Heart Association Council for High Blood Pressure Research
2000 Charles & Nora L. Wiley Faculty Award for Meritorious Research
2001-Present Fellow, American Heart Association
1994-2014 Editorial Board, *Infection and Immunity*
2013-2016 Editorial Board, *Microbes & Infection*
2014-2016 Editorial Board, *Clinical & Vaccine Immunology*
1998-2002 Associate Editor, *Journal of Immunology*
2002-2006 Section Editor, *Journal of Immunology*
2002-2006 Associate Editor, Society for Mucosal Immunology *Mucosal Immunology Update*
1998-2006 Member, Clinical Neuroimmunology and Brain Tumor (formerly BDCN4) Study Section, NIH
2000-2005 Member, Research Centers in Minority Institutions Review Committee, NIH-NCRR
2006-2010 Member, Oral, Dental and Craniofacial Sciences (ODCS) Study Section, NIH
1993-2014 Member, 36 Special Emphasis Panels for mucosal immunology and vaccine expertise
2010-2012 Member, College of CSR Reviewers

PUBLICATIONS (Selected from 124 papers and chapters)

Pascual, D.W. 2007. *Commentary:* Vaccines are for dinner. **Proc. Natl. Acad. Sci., USA 104: 10757-10758**.

Pascual, D.W., Riccardi, C., and Csencsits, K. 2008. Distal IgA immunity can be sustained by $\alpha_E\beta_7^+$ B cells in L-Selectin$^{-/-}$ mice following oral immunization. **Mucosal Immunol. 1:68-77**.

Rynda, A., Maddaloni, M., Mierzejewska, D., Ochoa-Repáraz, J., Maślanka, T., Crist, K., Riccardi, C., Barszczewska, B., Fujihashi, K., McGhee, J.R., and Pascual, D.W. 2008. Low-dose tolerance is mediated by the microfold cell ligand, reovirus protein σ1. **J. Immunol. 180: 5187-5200.**

Suzuki, H., Sekine, S., Kataoka, K., Pascual, D.W., Maddaloni, M., Kobayashi, R., Fujihashi, K., Kozono, H., McGhee, J.R., Fujihashi, K. 2008. Ovalbumin-protein σ1 M-cell targeting facilitates oral tolerance with reduction of antigen-specific CD4$^+$ T cells. **Gastroenterology 135:917-925.**

Pascual, D.W., Wang, X., Kochetkova, I., Callis, G., and Riccardi, C. 2008. Absence of CD8$^+$ lymphoid dendritic cell maturation in L-Selectin$^{-/-}$ respiratory compartment attenuates anti-viral immunity. **J. Immunol. 181: 1345-1356**.

Ochoa-Repáraz, J., Rynda, A., Ascón, M.A., Yang, X., Kochetkova, I., Riccardi, C., Callis, G., Trunkle, T., and Pascual, D.W. 2008. IL-13 production by regulatory T cells protects against experimental autoimmune encephalomyelitis (EAE) independently of autoantigen. **J. Immunol. 181: 954-968**.

Kochetkova, I., Trunkle, T., Callis, G., and Pascual, D.W. 2008. Vaccination without autoantigen protects against collagen II-induced arthritis via immune deviation and regulatory T cells. **J. Immunol. 181: 2741-2452**. *Featured in Research Highlights of Nature Clinical Practice Rheumatology 4:622, 2008.*

Yamanaka, H., Hoyt, T., Yang, X., Golden, S., Bosio, C.M., Crist, K., Maddaloni, M., and Pascual, D.W. 2008. A nasal IL-12 DNA vaccine co-expressing *Yersinia pestis* F1-V fusion protein confers protection against pneumonic plague. **Infect. Immun. 76: 4564-4573**.

Yamanaka, H., Hoyt, T., Bowen, R., Yang, X., Crist, K., Golden, S., Maddaloni, M., and Pascual, D.W. 2009. An IL-12 DNA vaccine co-expressing *Yersinia pestis* antigens protects against pneumonic plague. **Vaccine 27:80-87**.

Yang, X., Thornburg, T., Walters, N., and Pascual, D.W. 2010. Δ*znuA* Δ*purE Brucella abortus* 2308 mutant as a live vaccine candidate. **Vaccine 28:1069-1074**.

Yamanaka, H., Hoyt, T., Yang, X., Bowen, R., Golden, S., Crist, K., Becker, T., Maddaloni, M., and Pascual, D.W. 2010. A parenteral DNA vaccine protects against pneumonic plague. **Vaccine 28:3219–3230**.

Kochetkova, I., Golden, S., Crist, K., Callis, G., and Pascual, D. W. 2010. IL-35 stimulation of CD39$^+$ regulatory T cells confers protection against collagen II-induced arthritis via the production of IL-10. **J. Immunol. 184:7144-7153.**

Clapp, B., Golden, G., Maddaloni, M., Staats, H.F., and Pascual, D.W. 2010. Adenovirus F protein as a delivery vehicle for botulinum B**. BMC-Immunology 11:36**.

Staats, H.F., Fielhauer, J.R., Thompson, A.L., Tripp, A.A., Sobel, A., Maddaloni, M., Abraham, S.N., and Pascual, D.W. 2011. Mucosal targeting of a BoNT/A subunit vaccine adjuvanted with a mast cell activator enhances induction of BoNT/A neutralizing antibodies in rabbits. **PloS-ONE 6: e16532**.

Rynda-Apple, A., Huarte, E., Maddaloni, M., Callis, G., Skyberg, J.A., and Pascual, D.W. 2011. Active immunization using a single dose immunotherapeutic abates established EAE via IL-10 and regulatory T cells. **Eur. J. Immunol. 41:313-323**.

Clapp, B., Walters, N., Thornburg, T., Hoyt, T., Yang, X., and Pascual, D.W. 2011. DNA vaccination of bison to brucellar antigens elicits elevated antibody and IFN-γ responses. **J. Wildl. Dis. 47:501-510**.

Skyberg, J.A., Thornburg, T., Rollins, M.C., Huarte, E., Jutila, M.A., and Pascual, D.W. 2011. Murine and bovine γδ T cells enhance innate immunity against *Brucella abortus* infections. **PloS-ONE 6: e21978**.

Clapp, B., Skyberg, J.A., Yang, X., Thornburg, T., Walters, N., and Pascual, D.W. 2011. Protective live oral brucellosis vaccines stimulate Th1 and Th17 cell responses. **Infect. Immun. 79: 4165-4174**.

Huarte, E., Rynda-Apple, A., Riccardi, C., Skyberg, J.A., Golden, S., Rollins, M.C.F., Ramstead, A., Jackiw, L.O., Maddaloni, M., and Pascual, D.W. 2011. Tolerogen-induced interferon-producing killer dendritic cells (IKDCs) protect against EAE. **J. Autoimmun. 37:328-341**.

Yamamoto, M., Pascual, D. W., and Kiyono, H. M cell-targeted mucosal vaccine strategies. 2012. In: **Current Topics in Microbiology and Immunology** on Mucosal vaccines (Mucosal Vaccines: Modern Concepts, Strategies and Challenges). Chapter 3. P. Kozlowski, ed. Springer, Heidelberg, Germany. **Vol. 354:39-52**.

Jun, S-M., Clapp, B., Zlotkowska, D., Hoyt, T., Holderness, K., Maddaloni, M., and Pascual, D.W. 2012. Sublingual immunization with adenovirus F protein-based vaccines stimulates protective immunity against botulinum neurotoxin A intoxication. **Intern. Immunol. 24:117-128**.

Yang, X., Suo, Z., Thornburg, T., Holderness, K., Walters, N., Kellerman, L., Loetterle, L., Avci, R., and Pascual, D.W. 2012. Expression of *Escherichia coli* virulence usher protein attenuates wild-type *Salmonella*. **Virulence 3:29-42**. *Highlighted by C. C. Goller and P. C. Seed: Coming of AGE: Facile generation of attenuated vaccine strains through heterologous gene expression. Virulence 3:12 - 14, 2012*.

Yang, X., Skyberg, J.A., Cao, L., T T., Clapp, B., and Pascual, D.W. 2012. Progress in *Brucella* vaccine development. **Front. Biol. 10.1007/s11515-012-1196-0**.

Jun, S-M., Ochoa-Repáraz, J., Zlotkowska, D., and Pascual, D.W. 2012. Bystander-mediated stimulation of proteolipid protein-specific regulatory T (T_{reg}) cells confers protection against experimental autoimmune encephalomyelitis (EAE) via TGF-β. **J. Neuroimmunol. 245:39-47**.

Schepetkin, I.A., Kirpotina, L.N., Khlebnikov, A.I., Hanks, T.S., Kochetkova, I., Pascual, D.W., Jutila, M.A., and Quinn, M.T. 2012. Identification and characterization of a novel class of c-Jun N-terminal kinase inhibitors. **Mol. Pharmacol. 81:832-45**.

Skyberg, J.A., Rollins, M.C.F., Holderness, J.S.,Marlenee, N.L., Schepetkin, I.A., Goodyear, A., Dow, S.W., Jutila, M.A., and Pascual, D.W. 2012. Nasal Acai polysaccharides potentiate innate immunity to protect against pulmonary *Francisella tularensis* and *Burkholderia pseudomallei* infections. **PLoS-Pathogens 8:e1002587**.

Skyberg, J.A., Thornburg, T., Kochetkova, I., Layton, W., Callis, G., Rollins, M.C.F., Riccardi, C., Becker, T., Golden, S., and Pascual, D.W. 2012. IFN-γ-deficient mice develop IL-1-dependent cutaneous and musculoskeletal inflammation during experimental brucellosis. **J. Leuk. Biol. 92:375-387**.

Zlotkowska, D., Maddaloni, M., Riccardi, C., Walters, N., Holderness, K., Callis, G., Rynda-Apple, A., and Pascual, D.W. 2012. Loss of sialic acid binding domain redirects protein s1 to enhance M cell-directed vaccination. **PLoS-ONE 7: e36182**.

Yang, X., Thornburg, T., Suo, Z., Jun, S., Robison, A., Li, J., Lim, T., Cao, L., Hoyt, T., Avci, R., and Pascual DW. 2012. Flagella overexpression attenuates *Salmonella* pathogenesis. **PLoS One 7:e46828**.

Hendricks, J. M. , Riccardi, C., and Pascual, D.W. , and Hardy, M. E. 2012. 18β-glycyrrhetinic acid delivered orally induces isolated lymphoid follicle maturation at the intestinal mucosa and attenuates rotavirus shedding. **PLoS-ONE 7:e49491**.

Skyberg, J.A., Rollins, M.C.F., Samuel, J.W., Sutherland, M.D., Belisle, J.T., and Pascual, D.W. 2013. IL-17 protects against the *Francisella tularensis* live vaccine strain, but not against virulent *F. tularensis* type A strain. **Infect. Immun. 81: 3099-3105**.

Ongoing Research Support

Project Number (Principal Investigator) R01 AI-78938 (PASCUAL) 02/01/2009 - 01/31/2014
Source: NIH-NIAID
Title of Project *(or Subproject): Mucosal Therapy for Autoimmunity*
Goals: The objective for these studies is to develop a simplified method of inducing single dose tolerance and treatment of autoimmune disease. The mucosal targeting molecule, reovirus protein σ1, stimulates tolerance to genetically fused antigens. The proposed studies will discern the mechanisms responsible for meditating tolerance and ascertain which innate cells are involved for stimulating tolerant T cells.

Project Number (Principal Investigator) 1R01 AI-093372-01 (Pascual) 05/01/2011-04/30/2016
Source: NIH-NIAID
Title of Project *(or Subproject): Subunit Vaccines for Brucella Pathogens*
Goals: The major goal of this grant application is to test PotD and PotF subunit vaccines for protection against aerosol *B. melitensis, B. abortus*, and *B. suis* in mice and protection against *B. melitensis*-induced abortion in goats. Ultimately, these vaccines will provide proof-of-principle for eventual testing in humans.

Project Number (Principal Investigator) 1R01 AI-093370-01 (Mohamadzadeh) 08/01/2011-07/31/2016
Source: NIH/NIAID
Title of Project *(or Subproject):* Novel Multivalent Vaccine for Anthrax and Botulinum
Project Leader

Goals: The major goal of this grant application is to test the efficacy of *Lactobacillus*-based oral vaccines for anthrax protective antigen and botulinum heavy chain C-terminus. Ultimately, these vaccines will provide proof-of-principle for eventual testing in humans.

Project Number (Principal Investigator) P01 AT004986-01 (JUTILA) 10/01/2008 – 09/30/2014
Source: NIH/NCCAM
Title of Project *(or Subproject): CAMs as Counter Measures Against Infectious & Inflammatory Diseases PROJECT 3: Anti-Inflammatory Microbial CAM & Arthritis* (PASCUAL)
Goals: The major goal of this project is to investigate how our *E. coli* CFA/I fimbriae and other CAMs mediate protection against arthritis independently of collagen antigen.

Project Number (Principal Investigator): 1R01 AI102747 (Staats) 07/01/2012-06/30/2016
Source: NIH/NIAID
Title of Project *(or Subproject): Mucosal Vaccination to Protect Against HIV-1 Infection at Mucosal Sites*
Goals: The major goal of this grant application is to test the efficacy of our soluble adenovirus protein F fusion vaccines with HIV gp140 for testing by Duke Univ. investigators.

M. J. WINSHIP, M. D., F.A.C.P.
1627 West Main Street, Ste. 428
Bozeman, MT 59715
Home and Cell: (406) 522-0113
Email: mjwinship@gmail.com

- **Innovative senior life sciences professional**
- **Proven record of achievement in all aspects of product development**
    - **Product concept development from preclinical through clinical development**
- **Provided leadership and implementation for successful change of two research companies to product development units**
- **Skilled and thorough assessments of numerous new companies and product opportunities**
- **Detailed understanding of regulatory registration requirements and building of collaborative relationships with FDA**
- **Strengths**

    Strategic planning
    Understanding product use in the clinic
    Building collaborative and highly focused teams across different disciplines
    Changing company focus from research only to product development
    Assessment of new product opportunities

INDUSTRY EXPERIENCE

Operations and Development Experience

Activities	Direct Experience	Direct Supervisory Role
API & bulk drug – 3 companies		Yes
Process Chemistry – 2 companies		Yes
Formulation – 3 companies		Yes
Stability – 3 companies		Yes
Analyticals – physical and biological – 2 companies		Yes
pk-humans ADME	Yes	Yes
Pharmacology (animals) ADME	Yes	Yes
Pharmacology (human)	Yes	Yes
Toxicology	Yes	Yes
Regulatory-CDER, CBER, CDRH	Yes	Yes
Device QSR environment		Yes
15-20 FDA presentations-CDER & CBER	Yes	Yes
Irreversible enzymes	3 programs	3 programs
Reversible enzymes	4 programs	5 programs
QA/QC – pharmaceutical and device		Yes
Laboratory 20+ people	Yes	Yes
Project teams (~120 people)	Yes	Yes
Protocol development	Yes	Yes
Clinical Phase 1-2 US & International	Yes	Yes

Clinical Phase 3 US	Yes	Yes
Clinical Phase 3 in Asia	Yes	Yes
Clinical Phase 3 in Europe	Yes	Yes
Phase 4 trial for products-surveillance, Commercial Launch	Yes	Yes
Medical Safety-Chief Medical Officer-Drug Safety	Yes	Yes
Commercial development	Yes	Yes
Strategic Planning	Yes	Yes

Clinical Development, Regulatory and Evaluations Experience

Completed trials	Vaccines	Oncology	Anti-infectives	Allergy	Cytokines/ molecular	Eye	GU	Totals	Outside Product & Company Evaluations
Preclinical	4	6	6	1	3	1	1	21	36
Phase I	2	8	2		2	1	1	13	17
Phase II		5	1				1	4	7
Phase III	2	8	2	1				9	3
NDA	1	1	1	1				4	2

2011-2012 Drug and Device Development Consulting

- **Biomedical Systems**
  Senior Clinical Consultant

2009 Retired from full time work

2008-2009 Light Science Oncology, Bellevue, Washington
Chief Medical Officer

- Reduced work to part time
- Phase III hepatoma trial enrollment completed

2005-2008 Light Sciences Oncology, Snoqualmie, Washington

- Light Sciences Oncology was formed following $67 million funding and spin-off from Light Sciences Corporation in October 2005 to develop oncology indications

Chief Operating Officer and Chief Medical Officer

- Set up the operations and hiring for the new company
- Hired functional areas: CFO, Vice-President of Devices, and Head of Regulatory, IP
- Started and finished a Phase II hepatoma trial
- SPA obtained for Phase III hepatoma with FDA
- Phase III hepatoma trial started in Asia
- Phase II glioma trial started and finished in Eastern Europe
- SPA obtained for Phase III metastatic colorectal cancer with FDA
- Phase III metastatic colorectal cancer started in Europe
- Corporate Secretary
- Personally filed IND for BPH

2001-2005 Light Sciences Corp, Snoqualmie, Washington

Light Science has developed a light source and a photosensitizer system that destroys unwanted tissue. LSC has 3 major program areas: oncology, cardiovascular, and ophthalmology

2002-2005 Senior Vice President Research & Development, Chief Medical Officer

- Ophthalmology program developed and large deal with Pharmaceutical company made within 9 months of arrival
- Ophthalmology IND filed in 2004
- Cohesive, energetic and focused R&D team activated
- Phase I oncology trials completed and report submitted to FDA in 2003
- Phase II oncology trial started 2003
- Oncology strategy developed for registration trials and partnering
- Transitioned LSC from an IP boutique to development company

2001-2002 Senior Vice President, Oncology Products

- Reorganized the entire R&D group – Pharmaceuticals, Devices, Regulatory/QA Procedures, SOPs, Processes implemented Oncology IND filed within 7 months of arrival
- Overall Company Development strategy implemented

1998-2001 IDUN Pharmaceuticals, Inc, La Jolla, CA

Idun is a biopharmaceutical company focused on the design and development of small molecule human therapeutics that targets the pathways controlling programmed cell death.

Vice President, Medical Affairs

- Built a total pre-clinical and clinical product development program and processes
- Selected and took a bench compound through all the pre-clinical processes into clinical trial in 16 months

- Identified and prioritized clinical targets for potential products

1997-1998 IBAH, Blue Bell, PA

One of the top contract research organizations worldwide performing full development services for Pharmaceutical, Biotechnology, and Device Companies.

Vice President, West Coast Operations, Emeryville, CA

- Consolidated two offices into single location and brought the office on-line with company east coast headquarters in 3 months
- Implemented unified development approach for emerging technology companies

1994-1997 HOECHST MARION ROUSSEL (HMR), Kansas City, Missouri

One of the top global pharmaceutical companies, HMR was formed from Hoechst, Roussel-Uclaf, and Marion Merrell Dow in mid-1995 and has major R&D efforts in the US, Europe, and Japan.

Senior Director, North American Clinical Research, Kansas City, MO 1995-1977

- Responsible for Oncology/Infections Disease, Allergy, Alopecia, Cytokines and General

Medicine projects
- Designated as an Expert Advisor to the Infectious Diseases Global Therapeutic Area and as an Expert Advisor to the Oncology Global Therapeutic Area
- Member of the Oncology licensing committee that evaluated new product opportunities.

1994-1995 Director, Clinical Research, Global Therapeutic Area Infectious Diseases/Oncology, Marion Merrell Dow Inc. (MMD), Kansas City, MO

- Managed the global clinical development of Oncology/Anti-Infectives products
- Participated in the thorough examination and reorganization of the development program to reduce the time to registration of products
    - The strategy was a minimalist approach to do only the minimum number of trials and patient numbers consistent with good medical practice and necessary for registration of a single indication for a compound
    - No trials which did not support the primary indication would be done prior to submission
    - Following submission, while the regulatory review process was ongoing, additional trials to support other indications and other needs would be started
    - Time to registration was shortened, and the compound would bring in revenue while other indications were being studied
- Revised the oncology development program and shortened the clinical time down to 3.5-4 years
- Chaired an ad-hoc task force to examine career development in the clinical research department
    - Critical skill sets in clinical development were defined for the CRA level to Vice-President level
- Plans were instituted to increase each individual's skills to the next higher level
    - Other departments within MMD adopted these skill sets and criteria for career development and advancement for their personnel.
- Specifications for central laboratory selection were drawn saving company about $600,000 per year
- As part of an appointed 3 member team, assembled the results of an extensive internal assessment of the research capabilities within MMD
    - Integrated these with the current market desires of the commercial department
      Provided focus to the strategic direction of the various therapeutic areas,
    - Identified compounds and areas necessary for licensing-in, acquisition, and/or collaboration
- In 1995, appointed to the Faculty at Kansas University Medical School, Division of Infectious Diseases, Department of Internal Medicine.

1992-1994 IMMUNOMEDICS, Inc., Morris Plains, N.J.

Immunomedics is a biotechnology company developing monoclonal antibody agents for

diagnostic imaging and treatment of cancer and infectious diseases.

Medical Director for Clinical Research

- Managed the worldwide infectious diseases program clinical trials
  - In January 1994, the major compound in development had been in 10 subjects.
  - The infectious disease imaging program was rapidly advanced from early phase I to Phase III within 9 months
  - First phase III patient enrolled in November 1994
- Twenty-three new clinical sites for the infectious disease program were identified, and became operational within the first 6 weeks
  - 50-60 percent of time was involved in review of ongoing colorectal cancer trials
    - Developed a problem statement, global safety, and global efficacy for the CPMP expert report on the anti-colorectal antibody cancer imaging
    - Set up the lymphoma treatment program.

1989-1992 LEDERLE-PRAXIS BIOLOGICALS, Pearl River N.Y.

Lederle-Praxis Biologicals was a division of Lederle Pharmaceuticals. It developed and marketed vaccines in the United States and overseas.

Associate Medical Director - Clinical Research and Associate Medical Director - Professional Medical Affairs

- Conducted clinical trials on the Sabin Inactivated Polio Vaccine
  - The killed polio program originate in 1983, but was still only in phase I in adults
  - The program was reviewed and streamlined
  - Trials in 6 year olds and infant trials were accomplished
  - Phase III trials were initiated in 1991.
- Responsible for clinical portion of Herpes Simplex Vaccine Program
  - Changed the strategic intent of the program from a prevention program to a therapy program, thereby expanding the market.
  - Identified a human model of recurrent herpes
    Shortened the time to establish proof of concept (efficacy) down to one year
    Two years of development time were saved.
- Subsequently, three other vaccine programs were added to my responsibilities.
  - With the preclinical head, we instituted weekly liaison sessions between preclinical and clinical development.
- Three months after joining Lederle-Praxis, a second full-time position of Associate Director of professional medical affairs was added to my responsibilities
  - Both Professional Medical Affairs and Clinical Research duties were performed concurrently
- All Phase IV studies, regulatory, marketing, sales, advertising, and product launch activities associated with all licensed vaccine products were my responsibility

- Reorganized all card letters (standardized replies) and information files on licensed biological products
- Optimized promotional potential of information from clinical studies and other sources through liaison with Marketing and Sales, Advertising, Clinical Research and Development, Medical Editorial Services.

1972-1989 PRIVATE PRACTICE OF INFECTIOUS DISEASES and INTERNAL MEDICINE, Missoula, Montana

I had a large Internal Medicine and Infectious Diseases consultative practice which included adult and pediatrics infectious diseases

Consulting in all areas of medicine

Shared weekends with 2 oncologists for 10 years

Director of a regional and reference microbiology laboratory providing human and veterinarian microbiological services for a three state area

- Chaired and directed three hospital infection programs

Hospital pharmacy advisor

Active member of executive committee of the Hospital board of trustees

- Member and vice-chairman of the local human use committee

Other Activities

- Founder of the Rocky Mountain Pus Club (RMPC), a non-profit educational forum for the intermountain area.
- Consultant in Infectious Diseases to various agencies:
  Missoula County Department of Health
  Veteran's Administration Hospital at Helena
  Montana State Department of Health
  Teton Microbiology Laboratory in Idaho Falls, ID
- University faculty member
  Department of Microbiology, Montana State University
  Department of Internal Medicine, University of Washington School of M Medicine
  Department of Pharmacy, University of Montana
  Department of Microbiology, University of Montana
  Law School, University of Montana
- Instructed Internal Medicine Residents and Students for the University of Washington School of Medicine
  1-month tutorials for the 12 residents in internal medicine from 1974-1989
  3 week tutorial for 12 students in internal medicine from 1974-1989
- 42-50 Medical Lectures per year given from 1976-1989

- Premarket laboratory evaluations of the Streptococcal, Chlamydia, and Gonorrhea EIA test kits for Abbott Laboratories prior to commercial release
- Developed a rapid "Diagnostic Test for Vaginitis" in collaboration with Dr. C. McLaughlin, Alternate Diagnostics Laboratory
- Pharmacokinetic studies of cephaloridine and gentamicin
- Intradermal immunization with hepatitis-b vaccine
- Several commercial antibiotic and gastrointestinal pharmaceutical trials.

EDUCATION/ PROFESSIONAL TRAINING

- Fellowship in Infectious Diseases, University of California at Davis, Sacramento Medical Center, Sacramento, California, 1971-1972
- Residency in Internal Medicine, Riverside General Hospital, Riverside, California, 1969-1971
- Liaison Officer, USAF, Deseret Test Center, Salt Lake City, Utah, 1967-1969
- Rotating Internship, Riverside General Hospital, Riverside, California, 1966-1967
- M.D., Northwestern University Medical School, Chicago, Illinois, 1962-1966
- B.S. in Medicine, Northwestern University School of Medicine, Chicago, Illinois, 1962

BOARD CERTIFICATION:

- Geriatrics, 1988
- Infection Control, 1983
- American Board of Medical Microbiology and Public Health Microbiology, 1978
  Emeritus Diplomate, 1990 Board Recertification , 1982, 1986, 1989
- Infectious Diseases, 1976
- Internal Medicine, 1972 Recertification, 1980

ELECTED FELLOWSHIPS:

- Infectious Diseases Society of America, 1991 – 2002 (F.I.D.S.A.) Emeritus Fellow 2002
- American Board of Medical and Molecular Microbiology (ABMM) formerly Medical Microbiology and Public Health Microbiology, 1982 - (F.A.A.M.)
- American College of Physicians, 1975 - (F.A.C.P.)

FACULTY MEMBER:

- San Diego State University, San Diego, CA 1999-2001
- Department of Medicine, University of Kansas Medical Center, 1995-1998
- Department of Internal Medicine, University of Washington School of Medicine, Seattle, WA, 1974-1989
- Department of Microbiology, University of Montana, Missoula, Montana, 1973-1989
- Department of Pharmacy, University of Montana, Missoula, Montana, 1981-1989
- Department of Microbiology, Montana State University, Bozeman, Montana, 1987-1989

OTHER RELATED ACTIVITIES

PROFESSIONAL SOCIETIES:

- American Academy of Pharmaceutical Physicians, 1993 - Charter Member
- American Association for the Advancement of Science, 1983-2001
- American College of Physicians, 1972-present
- American Committee on Clinical Tropical Medicine and Travelers Health, 1989-1992
- American Society of Clinical Pathology (Associate Member), 1979-1989
- American Society for Clinical Pharmacology and Therapeutics, 1996-1999
- American Society of Internal Medicine, 1981-1989
  - Pharmaceutical and Therapeutics Committee, 1980-1986
  - National Chairman, Pharmaceutical and Therapeutics Committee, 1985
  - National Nominating Committee, 1981-1983
- American Society of Microbiology, 1972-present
  - Continuing Medical Education Review Committee, 1981-1982
  - Ad Hoc Committee-Proficiency Testing for Medicare Certified Laboratories, 1987
- American Society for Rickettsiology and Rickettsial Disease, 1981-1988
- American Society for Tropical Medicine and Hygiene, 1984-1989
- Clinical Immunology Society, 1992-1994
- Faculty of Pharmaceutical Medicine of the Royal Colleges of Physicians of the United Kingdom, Membership, 1996-1998
- Infectious Diseases Society of America, 1979-2002
  - Emeritus Fellow 2002
- International Northwestern Conference on Diseases in Nature Communicable to Man, 1977-1989
- Rocky Mountain Pus Club, 1981-1989
  - Secretary-Treasurer, 1984-1989
  - President and Founder, 1981-1983
- Society of Hospital Epidemiologists of America, 1982-1989
  - National Nominating Committee, 1986

EDITORIAL REVIEWER:

- Nature Medicine, 1998
- Clinical Infectious Diseases, 1982-1997
- Journal of Infectious Diseases, 1984-1990
- Archives of Internal Medicine, 1985-1988
- Chest, Book Reviews, 1986-1988
- American Society of Microbiology News, Book Reviews, 1982-1993
- American Society of Microbiology Educational Programs, 1979-1982

PUBLICATIONS:

- Becker W, Palestro DJ, Winship J, Feld T, Pinsky CM, Wolf F, Goldenberg DM. Rapid imaging of infections with a monoclonal antibody fragment (LeukoScan). Clinical Orthopedics & Related Research. (329):263-272, 1996 Aug.
- Becker W, Bair J, Behr T, Repp R, Streckenbach H, Beck H, Gramatzki M, Winship MJ, Goldenberg DM, Wolf F. Detection of Soft-Tissue Infections and Osteomyelitis Using a Technetium-99m-Labeled Anti-Granulocyte Monoclonal Antibody Fragment. J Nuclear Med. 35(9):1436-1443, 1994.
- Stevens DL, Tanner MH, Winship MJ, Swarts R, Ries KM, Schlievert PM, Kaplan E: Severe Group A Streptococcal Infections Associated with a Toxic Shock-Like Syndrome and Scarlet Fever Toxin A. New Eng J Med 321:1-7, 1989
- Winship MJ: Brucellosis in a Rural Area. In: Young EJ, Corbel MJ, eds. Brucellosis: Clinical and Laboratory Aspects. CRC Press, Inc. 1989.
- Winship MJ: Human Brucellosis. In: Kass EH, Platt R, eds. Current Therapy in Infectious Diseases. 3rd Ed. Decker, 1989.
- Smith J, Winship MJ: Prevalence of *Chlamydia trachomatis* and Genital Mycoplasmas in a Non- Metropolitan Population. Int J Fertility 32(6):453-455, 1987.
- Rivey MP, Docktor WJ, Winship MJ: Aminoglycoside Monitoring in the Neonate. Drug Intelligence and Clin Pharm 19, 1985.
- Winship MJ: Cat Bite Tularemia. Infectious Disease Newsletter 3(6), 1984.
- Winship MJ: Human Ophthalmitis Secondary to *Pasteurella multocida*. Proceedings 34th Annual Meeting of International Northwest Conference on Diseases in Nature Communicable to Man. Jan. Sept 1979.
- Winship MJ: Anaerobic Disc Space Infection. Rocky Mountain Med J. 76;153-155, 1976.
- Winship MJ: Coincident Infectious Mononucleosis and Ulcerative Colitis. Rocky Mountain Med J. 71:858-586, 1974.
- Winship MJ: Candida in the Blood Culture-What to Do Next? Rocky Mountain Med J. 71(5):271-274, 1974.
- Hoeprich P, Ingraham JL, Klecker E, Winship MJ: Development of Resistance to 5-Fluorocytosine in *Candida parapsilosis* During Therapy. J Inf Dis 130:112-118, 1974.
- Goldstein E, Winship MJ, Pappagianis D: Ventricular Fluid and the Management of Coccidioidal Meningitis. Ann Int Med 77:243-246, 1972.

AMANDA R. VOGSTAD

719 South Church #3,
Bozeman, MT 59715

Phone: 402.937.5770
Email: arvogsta@gmail.com

Education

Master of Science, **Veterinary Science** 2012
Specialization: Epidemiology
Advisor: Dr. David R. Smith
University of Nebraska-Lincoln
Lincoln, NE, USA

Bachelor of Science, Biological Sciences 2007
Specialization: Cellular Molecular Microbial Biology
University of Calgary
Calgary, AB, Canada

Professional Experience

Graduate Research Assistant August 2012- Present
Montana State University
Bozeman, MT, USA

- Evaluated the effects of imposed intake variation at high and low levels of milk replacer on Holstein steer performance, health, and carcass characteristics
- Used indirect calorimetry to quantify metabolic rate of steers varying in body weight
- Additional research activities: assessed performance of heifers fed low quality forage and supplemented with commercial protein blocks

Graduate Research Assistant August 2010- May 2012
University of Nebraska-Lincoln
Lincoln, NE, USA

- Evaluated the effectiveness of *E. coli* O157:H7 pre-harvest food safety interventions by building a stochastic simulation model in @Risk
- Performed a meta-analysis to evaluate efficacy of Type III secreted protein vaccine product for reducing *E. coli* O157:H7 carriage in feedlot cattle
- Additional research activities: identified risk factors associated with Summer Pneumonia in ranch calves and Cor Pulmonale disease in feedlot cattle in Western Nebraska

Research Project Manager 2007- August 2010
Feedlot Health Management Services Ltd.
Okotoks, AB, Canada

- Coordinated and managed activities associated with in-house and contractual feedlot research
- Effectively provided direction, training, and supervision, as well as input into performance reviews for the Research Assistant and Research Project Managers
- Responsible for maintenance of the GrowSafe System and NIR machine

- Assisted professional feedlot production consultants with delivering feeds and feeding services to feedlot clients

Junior Biologist 2002- 2003
HydroQual Laboratories – Golder Associates Ltd.
Calgary, AB, Canada

- Independently executed the following scientific tasks: daily laboratory maintenance, culturing of organisms, implementation of laboratory protocols and standard operating procedures, data entry, and reporting

Referred Publications/Technical Reports

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Stochastic simulation model comparing distributions of STEC O157 fecal shedding prevalence between cattle vaccinated with type III secreted vaccines and non-vaccinated cattle.*** Zoonoses Public Hlth. 2013;10.1111/zph.12069

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Assessment of heterogeneity of efficacy of a three-dose regimen of a type III secreted protein vaccine for reducing STEC O157 in feces of feedlot cattle.*** Foodborne Pathog Dis. 2013; 10:678-683

Abutarbush SM, Pollock CM, Wildman BK, Perrett T, Schunicht OC, Fenton RK, Hannon SJ, **Vogstad AR**, Jim GK, and Booker CW. ***Evaluation of the diagnostic and prognostic utility of ultrasonography at first diagnosis of presumptive bovine respiratory disease***. Can J Vet Res 2012; 76: 23-32.

Smith DR and **AR Vogstad**. ***Vaccination as a method of E. coli* O157:H7 *reduction in feedlot cattle.*** On-Farm Strategies to Control Foodborne Pathogens. Callaway TR, and TS Edrington, Eds. NOVA Science Publishers, New York. 2012 pp 133-142.

Burgess BA, Hendrick SH, Pollock CM, Abutarbush SM, **Vogstad AR**, Jim GK, and Booker CW. ***The development of a novel percutaneous lung biopsy procedure for use on feedlot steers.*** Can J Vet Res 2011; 75: 254-260.

Stephens TP, Stanford K, Rode LM, Booker CW, **Vogstad AR**, Schunicht OC, Jim GK, Wildman BK, Perrett T, and McAllister TA. ***Effect of a direct-fed microbial on animal performance, carcass characteristics and the shedding of Escherichia coli O157 by feedlot cattle.*** Anim Feed Sci Technol 2010; 158: 65-72.

Hannon SJ, Perrett T, Wildman BK, Schunicht OC, **Vogstad AR**, Fenton RK, Burciaga-Robles LO, Pollock CM, Jim GK, Berg J, and Booker CW. ***Efficacy of a florfenicol-flunixin meglumine combination product versus tulathromycin or ceftiofur crystalline free acid for the treatment of undifferentiated fever in feedlot calves.*** Vet Ther 2009; 10(4): 1-18

Perrett T, Wildman BK, Jim GK, **Vogstad AR**, Fenton RK, Hannon SJ, Schunicht OC, Abutarbush SM, and Booker CW. ***Evaluation of the efficacy and cost-effectiveness of melengestrol acetate in feedlot heifer calves in western Canada.*** Vet Ther 2008; 9(3): 223-240

Jim GK , Booker CW, Schunicht OC, Wildman BK, Perrett T, Fenton RK, Hannon SJ, Jacod LJ, Burciaga-Robles LO, and **Vogstad AR**. ***Evaluation of three inclusion levels of corn based dry distiller's grains with solubles (DDGS) in the finishing diet of feedlot steers in Alberta.*** Alberta Livestock Industry Development Fund Project #2008L013R

Jim GK , Booker CW, Schunicht OC, Wildman BK, Perrett T, Fenton RK, Hannon SJ, Jacod LJ, and **Vogstad AR**. ***Food animal veterinary student feedlot externship in Alberta.*** Alberta Beef Producers, ALIDF and ACAAF Project #2005ABP001

Abstracts & Presentations

Vogstad AR, Olson BE, Wurtz TT, and Duff GC. ***Use of a portable metabolic chamber for measuring resting metabolic rates in cattle of varying body weights.*** 2013 Western Section Meeting, American Society of Animal Science, Bozeman, MT. Abstract accepted.

Vogstad AR, Perz K, Sharon K, Spence K, Stokes B, Hoyt M, Wurtz T, and Duff GC. ***The effects of imposed intake variation at high and low levels of milk replacer on neonatal Holstein calf performance and health.*** MSU Animal Science Seminar, Bozeman, MT. Presented March 26, 2013.

Vogstad AR, Moxley RA, Kruse G, Grotelueschen D, Edwards T, and Smith DR. ***Risk factors associated with brisket disease (Cor pulmonale) in feedlot calves.*** Nebraska Veterinary Medical Association 116th Annual Convention, Omaha, NE. Presented January 26, 2012.

Vogstad AR, Kruse G, Grotelueschen D, and Smith DR. ***An outbreak investigation of summer pneumonia in western Nebraska ranch calves.*** Nebraska Veterinary Medical Association 116th Annual Convention, Omaha, NE. Presented January 26, 2012.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Simulation model of vaccinating cattle against STEC O157 for pre-harvest food safety.*** 2011 Conference for Research Workers in Animal Diseases, Chicago, IL. Abstract accepted. Presented December 5, 2011.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, Rogan D, Culbert R, and Smith DR. ***Meta-analysis of a three-dose regimen of a type three secreted protein vaccine for efficacy at reducing STEC O157 in feces of feedlot cattle.*** 2011 Conference for Research Workers in Animal Diseases, Chicago, IL. Abstract accepted. Presented December 5, 2011.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Simulation model of vaccinating cattle against STEC O157 for pre-harvest food safety.*** UNL Ruminant Nutrition Seminar, Lincoln, NE. Presented November 17, 2011.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, Rogan D, Culbert R, Smith DR. ***Meta-analysis of a three-dose regimen of a type III secreted protein vaccine for efficacy at reducing STEC O157 in feces of feedlot cattle.*** UNL Ruminant Nutrition Seminar, Lincoln, NE. Presented November 17, 2011.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Meta-analysis and simulation to determine the efficacy and effectiveness of vaccinating cattle against STEC O157 for pre-harvest food safety.*** UNL School of Veterinary Medicine and Biomedical Sciences Seminar, Lincoln, NE. Presented October 31, 2011.

Vogstad AR, Moxley RA, Erickson GE, Klopfenstein TJ, and Smith DR. ***Modeling Escherichia coli O157:H7 pre-harvest food safety.*** UNL Beef Committee Meetings, Meat Animal Research Center, Hastings, NE. Presented May 10, 2011.

Teaching Experience

Teaching Assistant, *Montana State University* Spring 2013
Classes: Calving (ANSC 215) and Livestock Management (ANSC 234)

Teaching Assistant, *Montana State University* Fall 2012
Classes: Beef Cattle Management (ANSC 434)

Guest Lecturer, *University of Nebraska-Lincoln* Fall 2011
Animal Science 101

Teaching Assistant/Guest Lecturer, *University of Nebraska-Lincoln* 2011-2012
Food Safety Beef Scholars

Professional Figure Skating Coach, *AB, Canada NE, USA* 2002-2003, 2007-2012
Freestyle, Dance, Skating Skills, Interpretive, Learn To Skate, Power Skate,

Memberships

American Society of Animal Science	2012-2013
Professional Skaters Association	2010-2013
USA Figure Skating Association Professional Coach	2010-2012
Skate Canada Professional Coach	2002-2003, 2007-2012
Women in Science and Engineering, *University of Calgary*	2003-2004, 2007
Biological Science Association, *University of Calgary*	2003-2006
Chemistry Students Society, *University of Calgary*	2003-2005
4-H Beef Member, *Hussar AB*	1996-2003

Additional Training

Beef Quality Assurance Collegiate Training	2013
Ethical Practice in Science	2013
ISEP Indirect Calorimetry Course	2013
ASAS Mixed Models Workshop	2013
GrowSafe Systems Ltd. Training Session	2010
Microsoft Level II Access Course	2010
Veterinary ICH Guidelines & Good Clinical Practice Training	2009
Microsoft Level I Excel and Word Course	2007