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IJS

Intermountain Journal of Sciences

The Intermountain Journal of Sciences (IJS) is a regional peer-reviewed journal that encourages scientists, educators and students to submit their research, management applications, or viewpoints concerning the sciences applicable to the intermountain region. Original manuscripts dealing with biological, environmental, health and human development, mathematics, molecular-cellular, pharmaceutical, physical and social sciences are welcome.

Co-sponsors/publishers include the Montana Academy of Sciences, the Montana Chapters of The Wildlife Society and The American Fisheries Society. It is the intent of the governing bodies of the co-sponsoring organizations that this journal replace and standardize printed proceedings from the respective annual meetings. Format and style should follow the *Guidelines for Meeting Abstracts Submitted to the Intermountain Journal of Sciences, 1st revision 2016.** It is the policy of the editorial board that abstracts from presentations at annual meetings be published in the last issue of ***IJS*** for that year of the annual meeting. Submission of manuscripts for review and publication without regard to membership is encouraged.

Baseline funding is provided by the co-sponsoring organizations. Long-term funding will be derived from page charges assessed manuscript authors at $60/page, sponsoring organizations at $40/page for annual meeting abstracts and annual subscriptions: student - $6, regular member - $15, patron member - $25, international member - $25 and library - $25. One time subscriptions are: life member - $150 and sustaining subscriber - $2,500.

The intent of the co-sponsors and editorial board is that ***IJS*** be expanded to a quarterly journal. Achieving that objective depends upon numbers of acceptable manuscripts received and available funding. The editorial board's policy is that contributing authors be assured of publication within 12 months of acceptance of their manuscript. It is also intended that ***IJS*** be converted to an eJournal.

The organizational staff is voluntary and consists of an editorial board, an editor-in-chief, a managing editor, associate editors, a business manager and a panel of referees. The editorial board is responsible for establishing policy and the chair of the editorial board serves as liaison to the editor-in-chief and managing editor. The editor-in-chief is responsible for determining acceptability and level of revision of manuscripts based on referees' comments and recommendation of an associate editor. The managing editor serves as supervisor for layout and printing and liaison to the sponsoring organizations. Associate editors and referees are selected on the basis of their field and specific area of knowledge and expertise.

Associate editors and referees judge submitted manuscripts on originality, technical accuracy, interpretation and contribution to the scientific literature. Format and style should follow the *Guidelines for Manuscripts Submitted to the Intermountain Journal of Sciences, Dusek 1995, 2nd revision 2016.** Organization may vary to accommodate the content of the article, although the text is expected to elucidate application of results.

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Financial Statement (1/01/17 - 12/31/17)

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Library Subscriptions		250.00
Patron Member		50.00
International Member		25.00
	Subscriptions Total	**$445.00**
Page Charges		5,835.00
Reprints and PDFs		175.00
Total Income		**$6,455.00**
Expenses:		
Design and Printing		$4,745.93
Mailing and Postage		$167.30
P. O. Box Rent		$132.00
Administrative and Bank Fees		$202.90
Reprints & PDFs		$150.00
Storage		$377.00
Supplies		$71.29
Website Layout & Update		$275.00
Outside Service (Software Programming)		$787.50
MSU Library Service (2016 Archiving Fee IJS)		$750.00
Total Expenses		**$7,658.92**
Balance 12/31/17		**$4,134.87**

Fred Nelson, Business Manager

Editorial Review Policy

The *Intermountain Journal of Sciences* (IJS) is a fully refereed journal.

Manuscripts are submitted to the Editor-in-Chief (EIC) for initial consideration for publication in the IJS. This review shall include, but not be limited to, appropriateness for publication in IJS, correct formatting and inclusion of a letter of submittal by the author with information about the manuscript as stated in the "Guidelines for manuscripts submitted to the *Intermountain Journal of Sciences*" (Dusek 1995, 2007) available on the IJS website, www.intermountainjournal.org under the Publish tab. This cover letter must also include a statement by the author that this paper has not been submitted for publication or published elsewhere. The EIC notes the date of receipt of the manuscript and assigns it a reference number, IJS-xxxx. The EIC forwards a letter of manuscript receipt and the reference number to the corresponding author. The corresponding author is the author who signed the submittal letter.

Three hard or digital copies of the submitted manuscript, with copies of the "Guidelines and checklist for IJS referees" attached are forwarded to the appropriate Associate Editor. The Associate Editor retains one copy of the manuscript and guidelines for his/her review, and submits a similar package to each of two other reviewers. A minimum of two reviewers, including the Associate Editor, is recommended for each manuscript. The two reviewers are instructed to return the manuscript and their comments to the Associate Editor. The Associate Editor then returns all manuscript copies and reviewer comments plus a recommendation for publication, with or without revisions, or rejection of the manuscript to the EIC. This initial review process is limited to 30 days.

The EIC then reviews the recommendations and all comments and notifies the corresponding author of the results of the review and the publication decision.

Acceptance

For accepted manuscripts, each copy of the manuscript containing comments thereon and other comments are returned to the corresponding author. Revised manuscripts are to be returned to the EIC in hard copy and four copies if further review is required. These copies can be submitted in digital form by email. The revised manuscript shall be returned to the EIC within 14 days of notification. Review of the revised manuscript by the Associate Editor and reviewers shall be completed and returned to the EIC within 14 days. An accepted manuscript will then be forwarded to the Managing Editor (ME) for final processing.

Rejection

Each manuscript that is rejected for publication is returned by the EIC to the corresponding author along with the reasons for rejection. The author is also advised that the manuscript may be resubmitted, provided all major criticisms and comments have been addressed in the resubmitted manuscript. The resubmitted manuscript may be returned to the initial review process if deemed appropriate by the EIC. If the manuscript is rejected a second time by either the EIC or the Associate Editor and reviewers, no further consideration will be given for publication of the manuscript in IJS. The corresponding author will be notified of this decision.

Reviewer Anonymity

The identity of all reviewers shall remain anonymous to the authors, called a blind review process. All criticisms or comments by authors shall be directed to the EIC; they may be referred to the ME or the Editorial Board by the EIC for resolution.

Manuscripts Submitted by Editors

Each manuscript submitted by an Associate Editor shall be reviewed by the EIC and a minimum of two other reviewers with expertise in the subject being addressed. Each manuscript submitted by the EIC shall be forwarded with the necessary review materials to the ME or chairman of the editorial board, who will serve as the EIC for that manuscript.

Abstracts

Only abstracts submitted from the annual meetings of the sponsoring organizations will be published in IJS. Other submissions of abstracts shall be considered on a case-by-case basis by the Editorial Board. Sponsoring organizations shall collect abstracts, review them for subject accuracy, format them in Microsoft Word and email them to Rick Douglass, the EIC (RDouglass@mtech.edu), on or before November 1. Each abstract shall be reviewed by the EIC to assure proper grammar, compliance with IJS Guidelines and for publication in the December issue of IJS. The Guidelines for Submitting Meeting Abstracts (Presentation or Poster) are available as a pdf on the IJS website under the Publish tab.

Commentary

Submissions concerning management applications or viewpoints concerning current scientific or social issues of interest to the Intermountain region will be considered for publication in the "Commentary" Section. This section will feature concise, well-written manuscripts limited to 1,500 words. Commentaries will be limited to one per issue.

Submissions will be peer reviewed and page charges will be calculated at the same rate as for regular articles.

Literature Cited

Dusek, Gary L. 1995, revised 2007. Guidelines for manuscripts submitted to the *Intermountain Journal of Sciences*.Int. J. Sci. 1(1):61-70. Revised guidelines are available on the Intermountain Journal of Sciences web site: (www.intermountainjournal.org)

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Quantifying and Managing Water Withdrawals in the Yellowstone River Basin: Increasing the Scientific Rigor

Trevor M. Watson[1], Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive, Moscow, ID 83844-1136 [1]

Dennis L. Scarnecchia, Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive, Moscow, ID 83844-1136

Brad J. Schmitz, Montana Fish, Wildlife and Parks, Box 1630, Miles City, MT 59301

Abstract

A scientifically-defensible system for accurate and precise quantification of existing water withdrawals and uses within the Yellowstone River Basin is necessary for effective water management. In conjunction with a data inventory of all known consumptive withdrawals from the Yellowstone River and its tributaries during the period 2006-2008, (municipal, industrial, irrigation agriculture and livestock sources), we conducted a physical inventory of surface withdrawals in 2006 to estimate the number of mainstem surface water users. Of the 687 identified water withdrawal sites, 113 were found to have screening devices present, 120 had no screens, and the screening status of 454 sites could not be determined. Ninety-two of the 687 water withdrawal sites identified during the physical inventory were not found to match with locations on the Department of Natural Resources and Conservation (DNRC) points of use or points of diversion. The lack of measured water withdrawals by most water users in the basin forces investigators to rely on indirect estimates of water use, which are inaccurate and propagate error through water use statistics. To improve the scientific credibility of data regarding the water withdrawals and improve conditions for native fish and other aquatic species, several suggestions are forwarded, including the need to screen all diversions, the need for an identification system to enable a withdrawal site to be specifically linked to a water right and the need for an accurate and precise system for measuring and reporting water withdrawals. Other identified needs are to complete the adjudication process in the state, to review the scientific evidence in support of the differential water use hierarchy in the Yellowstone River Basin, and to review terminology to eliminate, to the extent possible, ambiguous or imprecisely defined terms used in water usage. Short term benefits of applying more scientific rigor to the usage of water rights and the water management process will pay long-term dividends of more justifiable quantification of withdrawals, more reliable allocation of water, reduced litigation, and more effective conservation of native aquatic resources in the basin.

Key words: irrigation,water rights, instream flows, Montana

Introduction

"Today, not only irrigable lands cry for water, but also rivers, streams and the fish that inhabit them. New demands to serve the Northwest's growing population compete with instream needs for what little unallocated water remains." (Russell 1997, page 152)

As water demands have increased throughout the arid west in the past century, allocation and over-allocation of the limited supply have become potential sources of conflict. A few of the numerous and widespread examples include water allotment disagreements among states in the Colorado River Basin (Gelt 1997), out of basin water transfers to California that have dewatered the Owens River Valley

[1]Current Address: Oregon Department of Fish and Wildlife, 1850 Miller Island Road, Klamath Falls, OR 97603

(ICWD 2008), Klamath River disputes in southern Oregon and California over dams, declining fish populations, and failing water quality (Klamath 2009), and litigation between the State of Wyoming and Montana over provisions of the Yellowstone River Compact (Dengler 2007). In 2005, the Montana Legislature passed House Bill 22 (HB22) to accelerate the pace of water right claims examination and issuance of water right decrees and is requiring that all Montana water users share in the cost of completing the adjudication of Montana water rights by 2020 (Montana House Bill 22, 2005).

Water demand often is measured by amounts of withdrawal, i.e., water removal from ground- or surface water sources (Vickers 2001). Nearly all water withdrawals in the west are used for human economic activity. In aggregate, agricultural, industrial, municipal, and thermoelectric power water uses account for about 95% of all water withdrawals in the United States, although not all such withdrawals are considered consumptive, i.e. not immediately available for reuse (Kenny et al. 2009).

With the increasing demand for scarce water and recent and current basin-wide adjudications across the western U. S., many states are working to develop more accurate and precise requirements of users for reporting water withdrawals to help in their ongoing adjudications (Perramond 2012). In most localities, limited or lack of actual measurement of withdrawals has led to inaccurate estimates of historic and current usage, prolonging efforts to reach final adjudications (e.g., Washington: Bonkowski 2012; New Mexico: Perramond 2012). Inaccurately quantified withdrawals have crippled some states' ability to validate water demands in litigation. This problem was well illustrated in New Mexico v. Colorado (467 U.S. 310 (1984)) and further reinforced in the 2008 case between Montana and Wyoming (O'Regan and Shertzer 2011), when the Court required that the states have clear and convincing evidence standards to prove their case when seeking to enjoin the activities in one state that may negatively affect activities in another state. Some states that have experienced this problem have consequently enacted measures to more accurately quantify water usage (Perramond 2012).

In Montana, about 96.5% of all water withdrawals are for agriculture (Kenny et al. 2009). However, as in many locations nationwide, there is no uniform, formal, comprehensive metered approach for accurately and precisely documenting and monitoring total withdrawals. In the Yellowstone Basin, twenty-first century increases in water use demands (Cardwell et al. 1996; CFRBTF 2008) and the need for providing instream flows for the endangered pallid sturgeon (*Scaphirhynchus albus*), paddlefish (*Polyodon spathula*; Crance 1985; Firehammer and Scarnecchia 2007; Scarnecchia et al. 2009), other sensitive fish species (U. S. Army Corps of Engineers and Yellowstone River Conservation District Council 2015) and other aquatic life (Haddix et al. 1976; Penkal 1981; Proboszcz et al. 2003), have made it clear that the increasingly scarce water will need to be accounted for and conserved. Among the many western river basins dealing with water management issues, the relation between water issues and native fishes is particularly important for the Yellowstone. As the longest river in the United States that still retains a hydrograph close to natural, at least relative to other rivers of comparable size (White and Bramblett 1993), it remains a repository for many native species badly depleted or extirpated elsewhere in the broader Missouri River Basin (e.g. flathead chubs (*Platygobio gracilis*), sturgeon chubs (*Macrhybopsis gelida*), sicklefin chub (*Macrhybopsis meeki*), western silvery minnow (*Hybognathus argyritis*), Welker and Scarnecchia 2004, Scarnecchia et. al 2000; paddlefish (Scarnecchia et al. 2007), shovelnose sturgeon (*Scaphirhynchus platorynchus*); Everett et al. 2003; pallid sturgeon (*Scaphirhynchus albus*); Bramblett and White 2001; and the blue sucker (*Cycleptus elongatus*; Fig. 1). The pallid sturgeon has been listed as a federally

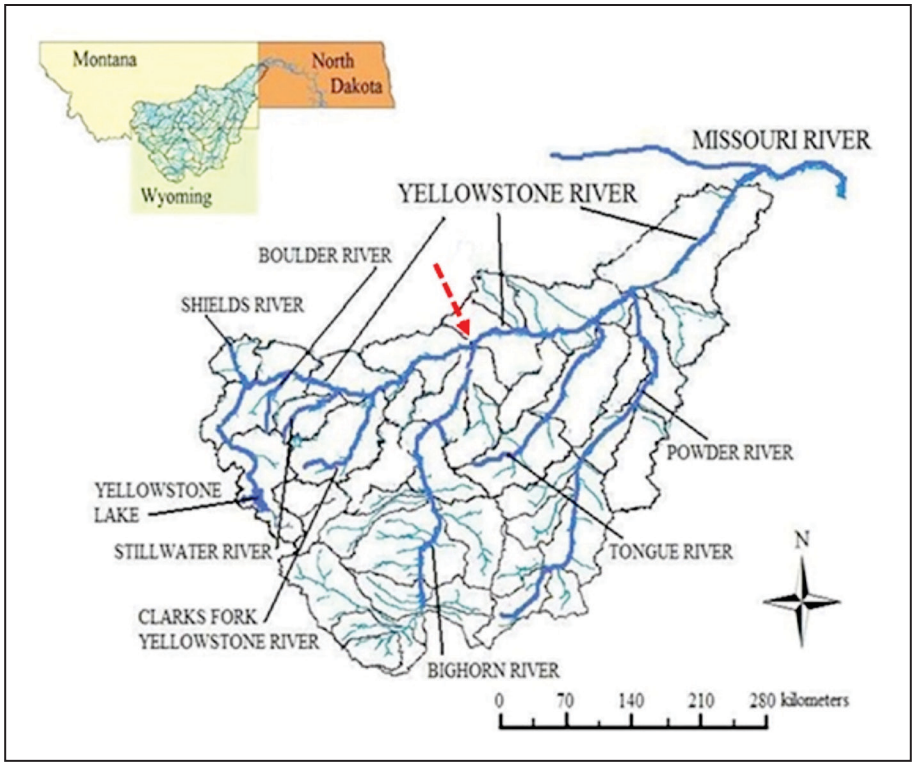

Figure 1. Montana, North Dakota, and Wyoming Map with Yellowstone River Basin Overlain. The dotted red arrow at the mouth of the Bighorn River shows where instream flow priority changes. Instream flows are second priority (behind municipal) westward, and third priority (behind municipal and agricultural) eastward.

endangered species since 1990 (U. S. Fish and Wildlife Service 2014). With so many human activities dependent upon the limited water resources and a wide array of demands on the water, increasing effort must be directed toward reconciling and planning the needs of various stakeholders and the needs for water withdrawal in relation to its retention in the river for the native biota. Compared to a century ago, there is today a wider array of legitimate demands recognized for water. As MacIntyre (1994) put it two decades ago: "Today, the west is settled… The challenge faced today in states such as Montana is to administer a limited resource for the benefit of all of the people of the state through more efficient water resource management" (p. 309).

Although many water use decisions are values-driven through the socioeconomic and political process, a major problem crippling effective water use management has been inadequate application of scientific knowledge toward it from various disciplines. A key aspect of this application involves accurate and precise measurement of defined quantities of water used for various applications. Decisions can then be made based, in part, on accurate and precise scientific data.

In the Yellowstone River Basin, an important first step is to inventory water withdrawals from the basin. In response to that need, a study was initiated in 2008 to : 1) inventory and quantify all current (2008) water rights for the Yellowstone River and its tributaries, including all state permitted water rights, all federal reserved and appropriated water rights and all other water reservations held on the rivers, 2) evaluate trends in irrigated agriculture development in the basin, 3) inventory and quantify all

known consumptive withdrawals from the Yellowstone River and its tributaries in 2006 using information from municipal, industrial, irrigation agriculture and livestock sources and 4) to conduct a physical inventory of water withdrawal sites along the mainstem and major tributaries. A key result of that completed study (Watson 2014) was the documentation of widely differing levels of measuring and reporting of water withdrawals, depending strongly on the category of withdrawals. Some categories of withdrawals were measured with accuracy and precision directly with meters (e.g., municipal and industrial withdrawals), making quantification relatively simple. Other categories of withdrawals were not measured, relying instead on indirect methods of estimation, making overall assessment of water usage difficult. In the absence of measurements and evaluations, the resulting withdrawal estimates are more prone to inaccuracies and unrecognized propagation of error (*sensu* Ku 1966) in the derived statistics.

To address this concern, our approach in this study was to focus on the fourth objective above, i.e., a physical inventory of water withdrawal sites along the mainstem and major tributaries. By starting at the source, i.e., the withdrawals, in relation to results of other estimation methods reported in Watson (2014), it will be possible to make specific recommendations regarding how water withdrawal information from the Yellowstone River and its tributaries can be scientifically quantified and improved, as well as made more legally defensible, in allocating limited water resources and in water law decisions.

Methods

To estimate the number of annual surface water withdrawal sites from the Yellowstone River and its major tributaries, whether documented or not, T. Watson and field assistants boated the Montana sections of the river and the seven major tributaries (Fig.1) from source to mouth and recorded all potential surface water withdrawals (e.g., any development and equipment to aid in water withdrawals). We scheduled the individual river inventories balancing their estimated peak irrigation season and safe water levels for boating in 2009 (Table 1). Potential water withdrawal sites were recorded if there was an active withdrawal or any of the following: reasonable access to the river with equipment or evidence of use nearby, fuel or electrical means within sight from the shore, evidence of stream alteration for stilling pool to withdrawal from, any man-made division of water from the channel, or if there was irrigation equipment (pumps, piping, fuel tanks, electrical hubs) present. For each potential withdrawal site photographs were taken, UTM coordinates were logged, on-site data collection was conducted on withdrawal type (diversion or pump), estimated diameter of headgate or mainline (small: 2.5-7.6 cm; medium: 7.7-20.3 cm; or large: >20.3 cm, including all diversions), energy source (electric or fuel) and pump type (centrifugal or turbine) and observations were made to determine any evidence of recent use, and whether there was any screening device present. Screening determination was presence or absence if clearly observed, there was no further evaluation about whether the screens could adequately prevent impingement or entrainment of all life stages of native fish. All field activities were conducted while staying below the visible high-water mark. Data collected and photos taken were then mapped using ArcGIS.

Table 1. Priority of rivers based on safe flows and irrigation demand.

River	Priority	Date
Clarks Fork Yellowstone	4	June 24 – 26
Shields	1	June 30 – July 4
Powder	3	July 6 – 9
Tongue	5	July 10 – 14
Boulder	2	July 17 – 20
Yellowstone	7,8,10	July 22 – 31
Stillwater	6	August 5 – 10
Bighorn	9	Aug. 29 – Sept. 3

Municipal and industrial withdrawal sites, in contrast to most irrigation withdrawal sites along the rivers, measure withdrawals; and those data were available to the authors from the municipalities. As a measure of municipal and industrial withdrawals, we obtained the 2006 water use data from each municipality and industrial water user in the basin. These measurements were obtained from recordings at their established measurement sites.

Results

During the physical inventory, 687 water withdrawal sites were identified and locations recorded. The Yellowstone River mainstem had the most withdrawal sites (317), followed by the Tongue River (144; Table 2). Each site varied widely from zero to five pumps present or large irrigation canals.

Table 2. Withdrawal sites in the Yellowstone River Basin Montana, 2009.

River	Number of Sites	Out of State Sites
Shields	20	NA
Boulder	20	NA
Stillwater	80	NA
Clarks Fork Yellowstone	35	NA
Bighorn	27	NA
Tongue	144	NA
Powder	44	NA
Yellowstone	317	23 ND
Total	687	23

The main types of water withdrawal methods used were centrifugal pumps, turbine pumps, domestic pumps (Fig. 2), irrigation canals without diversions, irrigation canals with partial river diversions, and irrigation canals with full river low-head diversions (Fig. 3). Sizes of intake pipes and headgate entrances ranged from less than 3 centimeters (approx.1 in) to 60cm (24 in) diameter mainlines to multiple 200 cm (78 in) headgates.

Of the 687 identified water withdrawal sites, 113 were found to have screening devices, present, 120 did not have screening devices, and 454 that could not be determined. Of greater interest, there were 100 irrigation canal withdrawal sites found in the basin and only 8 of them were screened. Identifying presence of screening devices could only be done for shallow water withdrawals, unused pumps on the banks and the open canal irrigation methods at the point of diversion.

Ninety-two of the 687 identified water withdrawal sites discovered during the physical inventory were not found to match with locations on the Department of Natural Resources and Conservation (DNRC) Water Right Query System for points of use or diversion. Of these, 54% had mainline diameters greater than 10cm (4 inches), were complete and established, and showed evidence of recent use. It must be noted, however, that 45 of the 92 undocumented withdrawals sites occurred on the Tongue River, where the DNRC's Tongue River Reservoir project holds water rights for use downstream. Therefore, an unknown percentage of these sites are probably legal

Figure 2. Examples of domestic, centrifugal, and turbine pumps.

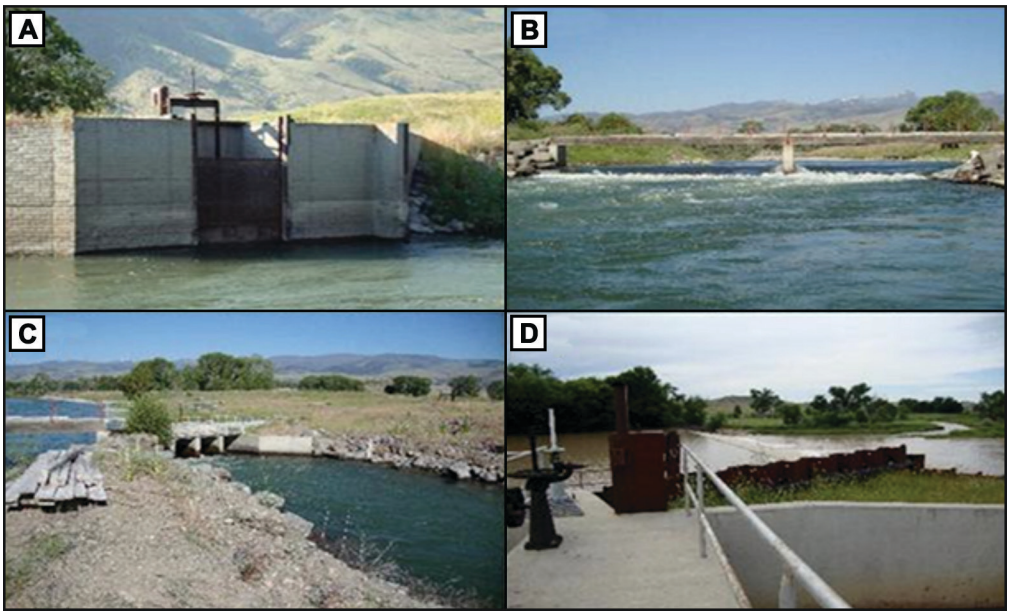

Figure 3. Examples of diversion types in the Yellowstone River Basin (A. Headgate without diversion; B. Side channel diversion; C. Multiple headgate partial channel diversion; D. Entire channel diversion with multiple headgates).

even though they do not have a water right at the point of diversion corresponding directly to them.

DISCUSSION

The results of the physical inventory highlighted some relevant scientific issues that deserve prompt attention. One major issue was lack of screening at greater than 90% of open canals diversions. Only 16 percent of the withdrawal sites (pump and canal) identified in the study were clearly screened. Although lack of screening was seldom considered important from an ecological standpoint a century ago, a large body of scientific evidence attests to the importance of screening irrigation diversions to protect aquatic life (Moyle and Israel 2005; King and O'Connor 2007; Gale et al. 2008). Lack of screening devices is of major concern in areas inhabited by species listed as endangered, threatened or of concern (Hiebert et al. 2000). Fish losses due to entrainment into irrigation devices can be substantial. Seechrist and Zehfuss (2010) found more than 6,000 fishes of 13 species entrained at the Fort Shaw diversion of the Sun River, Montana in 2003 and 2004. Heiner and Wagner (2016) reported on long term problems with entrainment of fishes at the St. Mary Diversion Dam on the Milk River, Montana. At larger withdrawal sites, entrained fishes can number into the hundreds of thousands, as estimated at Intake Diversion Canal, one of the larger irrigation canals, on the Yellowstone River (Hiebert et al. 2000). Screening of all diversions from the river, even small pump intakes, should therefore be a high priority, along with evaluation of the screening for effectiveness (Moyle and Israel 2005)

A second major issue arising from the field survey was the inability to link an actual water withdrawal with a specific water right. We were unable to match 14 percent of observed withdrawals with a water right, based on the withdrawal location in DNRC records. Under these conditions, it is often difficult to verify the legality of a pump site or withdrawal. Even if enforcement becomes an issue, which is seldom the case unless neighboring water users make a report, the water right system is confusing. When one tries to validate a claim by querying it on a map, water rights records are ambiguous in how much is

available for use (Watson 2014). A more reliable approach can be found to address this issue. First, the points of diversion need to be updated on the water rights. It might also be required for the site to be geolocated at the place of diversion and place of withdrawal. Concurrently, it would be beneficial to require that water appropriators clearly mark their withdrawal site with a water right identification linking back to the specific water right on any diversion structure or pump at the point of withdrawal. These approaches will permit easier enforcement of existing water laws and be a large step toward insuring legal use by water right holders, including instream users (Poff et al. 1997), and preventing illegal use by those without water rights.

A third issue emanating from the field survey and data base inventory is the recognition that there is not an adequate system for scientifically measuring and reporting water withdrawals associated with existing water rights. Accuracy of results from our inventory were far less than optimal because accurate estimates of irrigation use from metering are not required in Montana. Instead, water use can be reported in several different, approximate ways, including estimates of time water was withdrawn, estimates and calculations built with estimates on pump and canal capacities and daily averages. The state of Montana has the legal authority to make water users measure and report water use (MCA 85-2-113(2)(a)-(c)). The problem is one of ineffective use of that authority to require accurate and precise reporting.

Under these data limitations, efforts to identify trends in irrigation water usage in Watson (2014) were based on two indirect methods, involving many questionable assumptions designed to provide both high and low-end estimates. For example, lacking accurately measured water use data, Watson (2014) used agriculture census information for Montana and Wyoming by county within the Yellowstone River Basin to estimate total area of irrigated crops. He then used two methods to estimate the amount of water appropriated for irrigation for the 2006 growing season. The two methods were 1) the Irrigation Water Requirements (IWR) program, a minimum water requirement estimate for crop type based on evapotranspiration and 2) Montana DNRC's allowed water use, for new water rights, per irrigated hectare (i.e., the maximum water amount allowed per acre based on new water right standards). These cumbersome methods were in sharp contrast to directly acquiring measured water use estimates for municipal and industrial uses (Table 3).

A complicating factor in measuring water withdrawals and documenting their legality is that in our inventory, numerous water rights proved to be lacking in pertinent information when it came to amount of withdrawals, time of withdrawals and total amount of water used by the permitted water user. On many of these rights, there were no

Table 3. Annual Industrial and Municipal water withdrawals from the mainstem Yellowstone River for 2006.

Industrial	Withdrawn (m^3)	Reserved (m^3)	Percent Withdrawn
YRB	525,898,955	n/a	n/a
Municipal			
Laurel	2,744,957	8,820,629	31%
Billings	34,414,276	65,991,278	52%
Miles City	1,889,261	3,563,529	53%
Glendive	1,121,614	4,047,054	28%
Total (Municipal)	40,170,108	82,422,490	49%

dates of use specified, only maximum rates of withdrawal rather than total withdrawals. Water could therefore be withdrawn at some sites at that rate for the entire year. Also, some rights had time of use but did not list restrictions on rate or quantity of water used. Unlike municipal and industrial users with water rights, many other users simply did not provide the pertinent information to properly manage any restrictions on the water use.

Overall, improvements in these areas, i.e., screening, matching of withdrawal stations to existing water rights, and metering, will go far to put Montana's water withdrawals on a more scientifically- and legally-defensible basis. Although accurate water measurement and reporting are the most fundamental tools in water management, an identified challenge had been to find a way to minimize upfront costs of meters to those with water rights. Montana addressed this in 1991 with their Water Measurement Program awarding grants to offset the costs, so metering could have been implemented at least two decades ago. A step forward in scientifically defensible and egalitarian water reporting would be to make accurate, measured reporting mandatory for all water rights.

There are many benefits to improved reporting. In litigation, courts have favored states that have claims that are quantified and recorded and have made efforts to minimize wastes. Accurate reporting not only serves to assure the courts that the water is well monitored in the state, but it also demonstrates that a state recognizes the importance and value of the water, a finite resource, to its people. This rationale is well illustrated in New Mexico v. Colorado (467 U.S. 310 (1984)), where the court required that the states have clear and convincing evidence standards to prove their side of the case when seeking to enjoin the activities in one state that may negatively affect activities in another. In a situation where a downstream state tries to enjoin the activities of an upstream state because they are being harmed, or that the downstream state believes they are not receiving their fair share of water, for either of the states to present a strong case they would have to have their rights accurately and precisely quantified. It is nearly impossible for a state to prove by clear and convincing evidence that they have the right to the water and they are not short on supply due to their own inefficiencies without accurate and defensible water data.

Watson (2014) also discussed other areas where more scientific rigor would benefit water management in Montana. One area was the need to complete the adjudication process in the state, i.e., the legal process to determine who has a valid water right, how much water can be used, and who has priority during shortages (MacIntyre 1988). The scientific implication is that without Montana's water adjudication finalized, providing maximum volumes and rates per right, there is not an accurate estimate of the total water used and available for use. In Montana, the Confederated Salish and Kootenai Tribes (CSKT) -Montana Compact and other adjudication efforts stand to benefit from more accurate and reliable data.

A second identified need was for a review of the scientific evidence in support of the differential water use hierarchy in the Yellowstone River Basin. Although this is a value-laden process, scientific information should be considered. In the upper basin, i.e. above the confluence with the Bighorn River, municipal reservations have first priority, instream use has second priority, and agriculture has third priority. In contrast, in the lower basin, i.e. below the confluence with the Bighorn River to the North Dakota border, municipal has first priority, agriculture has second priority, and instream flow has third priority (Sobashinski and Lozovoy 1982). Ecological effects of this difference could be substantial. During a low water year when the instream flow reservation is all that is available in the river, a municipality with the same water right date (1978) could use some of the instream flow reservation water to fulfill its entitlement above the Bighorn River. Below the Bighorn River, however, both reserved municipalities and irrigation operations can

withdrawal from the river preferentially over the allocation for fish and aquatic life, potentially rendering the instream fish and wildlife allocation irrelevant and draining the river.

The differential prioritization of reservation usage between the upper and lower portions of the basin is a clear manifestation that instream values for native fishes have historically not been of primary concern. Although it might be argued by some that the blue-ribbon trout fisheries of the upper basin (Kerkvliet et al. 2002) are more economically important than the cool and warmwater species of the lower basin, the more diverse and more ecologically specialized native fish community of the lower basin, where more private lands exist and agriculture is more dominant, is more imperiled yet of lower priority in water allocation decisions. In recent decades, the recognition of the scientific importance of native biotic diversity has also increased the profile of the native fauna of the lower Yellowstone River (Werdon 1992; White and Bramblett 1993; Scarnecchia et al. 2008; Everett et al. 2004; Welker and Scarnecchia 2004). An important, nationally recognized fishery for paddlefish (*Polyodon spathula*) has also developed (Scarnecchia et al. 2008). As many native Missouri River species have declined, the importance of the lower Yellowstone River as high-quality fish habitat for species survival has become recognized. In terms of ecological significance, it is now understood that the river is a unified and an equally valuable resource from source to mouth, and that maintaining a natural flow regime in this and other rivers is critical to survival of many native fish species (Poff 1997; Xenopolis et al. 2006; Poff and Zimmerman. 2010).

A third area in need of more rigor identified by Watson (2014) is terminology used in water policies. Ambiguous or imprecisely defined terms continue to need clarification and where possible, quantification, as has been pointed out in past decades (Stone 1993; MacIntyre 1994). Terms such as salvaged water, beneficial use, duty of water, point of use, and waste would benefit from additional consideration and specifications in any new water management plans.

Ultimately, it is in all water users' best interests to make sure that the latest scientific methods and data collection and monitoring approaches are being used in Yellowstone River water management, and that the water withdrawals are accurately monitored and recorded. Short term benefits of applying more scientific rigor to the water management process will pay long term dividends of more defensible quantification of withdrawals, more effective allocation of water, reduced litigation, and more effective conservation of native aquatic resources in the basin.

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Characterizing Bighorn Sheep Foraging Sites Using the Modified Robel Pole in the Southern Black Hills, South Dakota

Chadwick P. Lehman, South Dakota Game, Fish and Parks, 13329 US Hwy 16A, Custer, SD 57730
Tess M. Gingery, South Dakota Game, Fish and Parks, 13329 US Highway 16A, Custer, SD 57730
Kyle D. Kaskie, South Dakota Game, Fish and Parks, 13329 US Highway 16A, Custer, SD 57730
Daniel W. Uresk, USDA Forest Service, 231 East Saint Joseph Street, Rapid City, SD 57701

Abstract

Evaluating foraging behavior of bighorn sheep (*Ovis canadensis*) and filling information gaps for their habitat requirements is important for population level management in the southern Black Hills of South Dakota. Our objectives were to: (1) evaluate the overall summer foraging area post lambing use during July and August for standing herbage with the modified Robel pole (1.27 cm bands) with visual obstruction readings (VOR) related to clipped herbage at ground level; (2) calibrate the Robel pole visual obstruction (bands) with clipped vegetation; and (3) develop guidelines for monitoring the landscape of the bighorn sheep foraging areas. The study area is located in a ponderosa pine (*Pinus ponderosa*) savanna with few shrubs and dominated with native grasses. Each transect had 10 visual obstruction (bands) stations spaced 10 meters apart with 4 visual obstruction readings at each station. At 4 stations, total vegetation was clipped at ground level within a 0.25-m^2 circular hoop. Clipped standing herbage ranged from 418 kg/ha to 3731 kg/ha with a mean of 1519 kg/ha. VOR measurements ranged from 0.2 cm to 14.9 cm with a 3.9 cm mean. Calibration of the modified Roble pole (visual obstruction of bands) with transect means using linear regression reliability predicted average clipped standing herbage (dry weights) within the bighorn sheep foraging area. The relationship was significant ($R^2 = 0.65$; $F_{1, 27} = 50.75$, $P < 0.01$). Cluster analysis (ISODATA) applied to the pole readings (VOR) and herbage resulted in 3 categories: short, intermediate and tall. We recommend 14 Robel pole transects (100 m in length) for VOR measurements within key foraging areas for future monitoring of herbaceous biomass for bighorn sheep. Foraging sites were in areas with little overstory tree canopy, close to rocky escape terrain, and where abundant grasses and forbs had little woody debris. The modified Robel pole provides a simple, reliable and cost effective alternative to clipping vegetation and obtaining dry weights.

Key words: Black Hills, *Ovis canadensis*, bighorn sheep, herbaceous biomass, foraging, Robel pole, vegetation

Introduction

Bighorn sheep (*Ovis canadensis*) populations have experienced significant declines across their range from the late 1800s through the mid 1900s as a result of diseases introduced from domestic livestock, unregulated hunting, habitat loss, and competition for foraging resources from domestic livestock (Beecham et al. 2007). Bighorn sheep need resources that contain adequate amounts of forage, escape terrain, lambing and loafing areas, water, and movement corridors (Brewer et al. 2013). Vegetation change due to overgrazing or shrub invasion can make previously occupied range unsuitable from the standpoint of forage quality and quantity (Risenhoover and Bailey 1985, Etchberger et al. 1989). Forage production and quality are factors that can regulate bighorn populations (Stelfox 1976). Ensuring adequate bighorn sheep habitat can be a significant challenge for managers, particularly in the Black Hills where ponderosa pine (*Pinus ponderosa*) can regenerate quickly leading to increased

tree density and loss of open areas (Shepperd and Battaglia 2002, Battaglia et al. 2008). Specific habitat resources important to bighorn sheep typically include slopes >50% slope, less distance to escape terrain (<320 m), and less overstory canopy cover or lack of dense tree vegetation (Geist 1971, Tilton and Willard 1982, McCarty and Bailey 1994, Sweanor et al. 1996, Johnson and Swift 2000). Escape terrain has been described as any habitat such as cliffs and steep hillsides (Geist 1971). Grazing by domestic or feral animals on bighorn sheep ranges can degrade and dramatically reduce availability of preferred forage and contribute to the spread of invasive or noxious plant species (Brewer et al. 2013). Bighorn sheep primarily forage on grasses and forbs, and determining the amount of herbaceous biomass at foraging sites is needed for subsequent monitoring (Chapman and Feldhamer 1982).

Monitoring herbaceous biomass use on rangelands by direct clipping measurements is time consuming, expensive, limited to sample size and slow to finalize estimates of herbage for management decisions. To meet the increasing demand for intensive monitoring of vegetation for livestock grazing and wildlife habitat on public rangelands, the modified Robel pole is widely used and cost-effective method for monitoring (Robel et al. 1970, Benkobi et al. 2000; Uresk and Benzon 2007; Uresk et al. 2009). Once the relationship between visual obstruction readings and standing herbage has been calibrated, the modified Robel pole provides a quick, yet effective tool to estimate standing herbage (Robel et al. 1970; Benkobi et al. 2000). The primary advantage of using techniques that have been calibrated to actual measurements (i.e. clipping vegetation) is that they are more accurate than ocular estimates (Kershaw 1973).

The Western Association of Fish and Wildlife Agencies Wild Sheep Working Group has identified several key management goals for wild sheep. A primary focus is to optimize quality and quantity of bighorn sheep habitat throughout the range of this iconic species. Further, management direction for conservation efforts of bighorn sheep in Region 2 of the U.S. Forest Service includes managing bighorn habitat to restore, enhance, or maintain vegetative openness adjacent to bighorn escape cover and along movement corridors (Beecham et al. 2007). Our objectives were to: (1) evaluate the overall summer foraging area post lambing use during July and August for standing herbage with the modified Robel pole (1.27 cm bands) with visual obstruction readings (VOR) related to clipped herbage at ground level; (2) calibrate the Robel pole visual obstruction (bands) with clipped vegetation; and (3) develop guidelines for monitoring the landscape of the bighorn sheep foraging areas. Further, we provide fine scale resource characteristics such as distance to escape cover, overstory and understory canopy cover, woody debris, and slope at foraging sites.

Study Area

Our study was located in the southern Black Hills of South Dakota on public land administered by the USDA Forest Service in Custer County, located in the southern Black Hills physiographic region (Flint 1955). Our study area was adjacent to Jewel Cave National Park and was 26 km^2 in size using a minimum convex polygon of all foraging site locations sampled during the study. Elevations varied from 1488 m to 1908 m. The Black Hills National Forest is dominated by ponderosa pine, but a wildfire in 2000 created open-canopied areas composed of primarily grasslands and shrublands. Western snowberry (*Symphoricarpos occidentalis*), chokecherry (*Prunus virginiana*), and common juniper (*Juniperus communis*) are common shrubs (Hoffman and Alexander 1987). Common native grasses include needle and thread (*Stipa comata*), green needlegrass (*Stipa viridula*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), and little bluestem (*Schizachyrium scoparium*); Larson and Johnson 1999). Non-native plants such as Kentucky

bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*) were also common.

Average annual precipitation was 49.91 cm. Precipitation from April through August was 31.95 cm and 49.58 cm for 2014, and 2015 respectively (National Climatic Data Center 1981-2015). Average annual temperature was 7º C for the study area (National Climatic Data Center 1981-2015).

Methods

Capture and Radio-telemetry

Bighorn sheep were captured during January 2014 utilizing netguns from helicopters in northeastern Montana. Following capture, sheep were blindfolded and equipped with a very high frequency (VHF) transmitter (Telonics Inc., Mesa, AZ.). Sheep were aged as adults (> 20 months) or yearlings (18-20 months of age) by evaluating lower incisors (Dimmick and Pelton 1994). Following capture, sheep were loaded into enclosed trailers and were transferred via vehicle and trailer from Montana to Hells Canyon in the southern Black Hills of South Dakota. Sheep were released on 7 January 2014.

Radio-marked sheep were systematically located and observed throughout the summer period, i.e., 15 July - 31 August, during 2014 - 2015. Visual locations were marked with a Global Positing System (GPS) where sheep were foraging and not disturbed. Within 3-5 days following the observation foraging site measurements were collected at those sites.

Foraging Site Measurements

We measured fine scale vegetative characteristics along a 100-m transect centered at each foraging observation oriented along a contour (0.04 ha plot). Overstory canopy cover was recorded at 1-m intervals along these transects (n = 100) using a GRS densitometer (Stumpf 1993). We estimated percent canopy cover of total herbaceous cover, grass, forbs, and shrubs in a 0.1 m^2 quadrat (Daubenmire 1959) at 3-m intervals along transects (n = 33). Aspect was recorded using a compass as the prevailing downhill direction from the site; percent slope was estimated along this same gradient with a clinometer. Distance (m) to nearest escape terrain, or granite rock outcropping, was measured using a range finder. Downed woody debris (metric tons/ha) was interpolated using a pictorial guide (Simmons 1982).

We determined understory herbaceous biomass at GPS locations where we observed bighorn sheep foraging sites using the following protocol. We used a modified Robel pole marked with alternating colors at 1.27-cm increments (Robel et al. 1970, Uresk and Benzon 2007) to characterize visual obstruction readings (VOR) from vegetation at sites. VOR measurements were centered at the foraging site and then taken at 10-m intervals (n = 10) along transects. With the pole positioned on the transect VOR's were made from a distance of 4 m with the reader's eye at a height of 1 m. We recorded 4 VOR's (one in each cardinal direction) where the lowest visible band was recorded at each for the 4 readings and averaged for the pole station (Robel et al. 1970). We clipped standing herbage to ground level within a 0.25 m^2 circular plot located and centered at each Robel pole station at 20, 40, 60, and 80 m. Vegetation was oven dried at 60˚ C for 48 hours and weighed to nearest 0.1 g. Robel pole measurements were correlated with dried herbaceous biomass to estimate standing herbage expressed as kg/ha (Uresk and Benzon 2007).

Statistical Analyses

All VORs and clipped herbage were averaged by transect for analyses. Relationships between VOR and herbaceous biomass were analyzed using linear regression with 90% prediction intervals. Regression models alone are not satisfactory to provide guidelines for resource management. Probability plots were examined graphically for normality of residuals. We implemented linear regression with the "glm( )" function in R version 3.1.0 (R Development Core Team 2014) (R Version 3.1.0, 2014, www.R-project.org/,

accessed 1 Apr 2014). Significance was set at $\alpha = 0.05$.

Non-hierarchical cluster analysis (ISODATA) was used (transect means, VOR and clipped herbage) to develop standing herbage resource categories for guidelines to evaluate grazing for allotments and pastures as it pertains to bighorn sheep management (Ball and Hall 1967; del Morel 1975). Resource categories of standing herbage included short, intermediate, and tall. Minimum and maximum thresholds for each category were computed using 95% confidence intervals (CI). The difference between lower and upper CI bounds across categories was divided by 2 and added to the lower bound and subtracted from the upper bound to define the ranges of each standing herbage category.

Visual obstruction readings and kg/ha were standardized to give equal weight for analyses (individual data subtracted from the sample mean/standard deviation). Estimated number of transects to achieve estimates to be within 20% of the mean with an 80% confidence level were evaluated on the regression variance (Cochran 1977). Future landscape level monitoring of standing herbage (number of transects) for bighorn sheep habitat, or in our case study 35% of the area from the minimum convex polygon was defined as a foraging area (Figure 5 in Benkobi et al. 2000; Uresk and Mergen 2012).

Results

A total of 18 bighorn sheep ($n = 16$ adult ewes, $n = 2$ male lambs or yearlings during second year) were included in our analyses, resulting in 36 summer foraging sites measured during 2014-2015. Relationship between VOR and herbaceous biomass was significant but not very predictive ($R^2 = 0.29$; $F_{1, 34} = 13.83$, $P < 0.01$). Removal of transects with >30% shrub cover, based on understory cover estimates resulted in 29 foraging sites, but improved the regression fit ($R^2 = 0.65$; $F_{1, 27} = 50.75$, $P < 0.01$; Figure 1). Herbage ranged from 1014 kg/ha to 3263

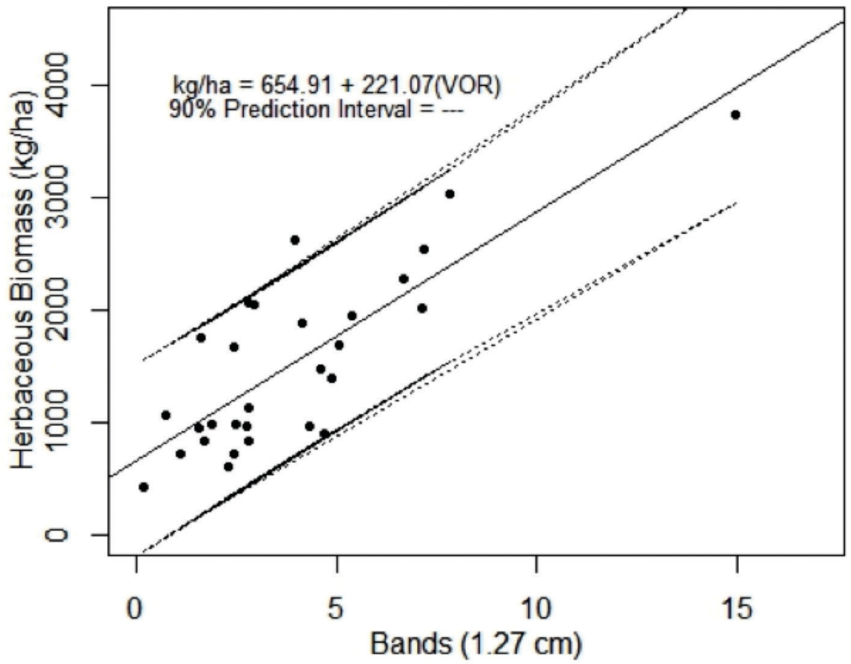

Figure 1. Model and scatter plot of dry weight herbaceous biomass (kg/ha) in relation to Robel pole visual obstruction bands that were in 1.27 cm intervals with 90% prediction intervals from the southern Black Hills, South Dakota, 2014-15.

kg/ha across short, intermediate, and tall categories using cluster analysis and 95% CI at foraging sites (Table 1). Cluster analyses (ISODATA) based on transect means for VOR's and clipped herbage resulted in 3 distinct minimum-variance VOR categories. These VOR categories were short (1.62–2.96), intermediate (2.97–5.12) and tall (5.13–11.80) (Table 1). Foraging sites were typically in areas with little overstory tree canopy, close to rocky escape terrain, and where abundant grasses and forbs had little woody debris (Table 2). Monitoring of the total area occupied by bighorn sheep would require 14 Robel pole transects located at random. Results from the 14 transects would be 80% confident to be within 20% of the mean.

Discussion

Providing baseline data at foraging sites for bighorn sheep will fill needed information gaps for bighorn sheep habitat management (Brewer et al. 2013). Depending upon the geographic location, summer range for bighorn sheep is often open-canopied areas with grasses, sedges (*Carex* spp.), and a diversity of forbs used as forage (Valdez and Krausman 1999). Grasses, followed by forbs and shrubs, were

Table 1. Visual obstruction categories resulting from cluster analysis for short, intermediate, and tall bands (1.27 cm, 0.5 inch) on a modified Robel pole with corresponding standing herbage ($kg \cdot ha^{-1}$). Band represents visual obstruction reading (VOR).

Category		Minimum	Mean	Maximum
Short (*n*=14)[a]	Band	1.62	2.27	2.96
	kg/ha[b]	1014	1157	1309
Intermediate (*n* =10)	Band	2.97	3.78	5.12
	kg/ha	1310	1491	1787
Tall (*n*=5)	Band	5.13	8.75	11.80
	kg/ha	1788	2589	3263

[a] Number of transects

[b] Kg/ha based on band-weight regression equation

Table 2. Characteristics of summer foraging sites for bighorn sheep in the southern Black Hills, South Dakota, 2014–2015. Metrics in table were from 29 sites where understory shrub cover was ≤30%.

Variable	Mean	SE
Tree canopy cover (%)	4.48	2.06
Total understory cover (%)	64.30	2.70
Understory grass cover (%)	43.98	3.57
Understory forb cover (%)	23.78	2.74
Understory shrub cover (%)	15.73	1.90
Distance to escape cover (m)	36.59	5.29
Slope (%)	28.14	3.08
Woody debris (metric tons/ha)	8.56	0.63
Herbaceous biomass (kg/ha)	1519.18	148.00
Visual obstruction readings (1.27 cm bands)	3.91	0.54

the primary forage available to sheep in our study. Forage quality is an important factor for ungulate ecology but there can be several limiting factors such as temperature regulation (Belovsky 1981, Millspaugh et al. 1998), requirement of minerals (Schwantje 1988), risk of predation (Berger 1978, Bowyer et al. 1998, Bleich et al. 1997), and forage availability (Rominger 1983, Vivas and Saether 1987). Diets of bighorn sheep are typically comprised of grasses, forbs, and shrubs but can vary markedly depending upon gender and geographic location (Valdez and Krausman 1999, Schroeder et al. 2010). Most bighorn sheep migrate seasonally over an altitudinal gradient (Geist 1971) which can influence their diet seasonally and geographically. Our study population does not exhibit spatial or altitudinal migrating behavior and foraging availability of grasses and forbs was greater than for shrubs. Shrub availability was greater for some bighorn populations that exhibit altitudinal migrations (Risenhoover and Bailey 1985, Greene et al. 2012).

In addition to selecting for forage availability, sheep selected for areas close to escape terrain and for open areas providing good visibility (Risenhoover and Bailey 1985, McCarty and Bailey 1994, Sweanor et al. 1996, Johnson and Swift 2000). A large wildfire had burned much of the area used by our study population; sheep are attracted to ranges that have been burned because such areas have been cleared of trees and woody debris that can reduce visibility while also providing adequate forage (Peek et al. 1979, Riggs and Peek 1980).

The modified Robel pole was adequate at predicting herbaceous biomass once we removed sites with greater than 30% shrub cover. Our study was not as predictive as previous studies using the modified Robel pole in meadow habitats where $R^2 \geq 0.80$ (Uresk and Benzon 2007, Uresk et al. 2009). The greater percentage of shrubs in the understory (mean of roughly 16%) may have lowered predictions, particularly given the weights of biomass were slightly heavier than biomass measured in meadow habitats with similar VOR bands (Uresk and Benzon 2007, Uresk et al. 2009). When we included sites with greater shrub density (>30%) we had difficulty predicting herbaceous biomass as shrubs were heavier than grasses and forbs with comparable visual obstruction readings.

We recommend a range of 1310 – 1787 kg/ha herbaceous biomass be made available for wild sheep at summer foraging areas, a range identified as the intermediate grouping in our cluster analysis. This range is similar but more restrictive to what was found on summer range in the Pusch Ridge Wilderness in Arizona (seasonal range 851–1,985 kg/ha; Mazaika et al. 1992). The three resource categories defined by cluster analyses provide useful guidelines for management of bighorn sheep. The short category is the minimum herbage required to maintain the sheep through winter or drought periods. Monitoring of the available sheep habitat for this short category is required to maintain the herd with adequate forage, and if forage falls below this critical value emergency supplemental feeding may be required during drought and harsh winters. Intermediate category will sustain the current needs for forage. However, the tall category is surplus feed that is available for summer grazing and harsh winter months. Bighorn sheep from our study population had high annual ewe survival (≥87%) and lamb production through winter (≥ 45 lambs:100 ewes) (SDGFP, unpublished data).

Monitoring at the landscape level and sampling efficiency is related to the area of land occupied by the bighorn sheep (see Figure 5, Benkobi et al. 2000; Uresk and Mergen 2012). The area currently occupied by bighorn sheep is 26 km^2 and equals 10 sections of land (259 ha/section or 640 acres/section), which results in 40 quarter sections. Therefore, 35% of the quarter sections to be sampled would equal 14 transects for monitoring the total area. We recommend stratifying the area into 3 strata as a minimum to randomly distribute the 14 transects among the 3 strata. Once the random locations are located (14), one transect is required to be sampled at each

of the locations. If the area of concern increases, sampling adjustments can be determined. The level of confidence of this monitoring is established to be within 20% of the mean at an 80% confidence level.

Management Implications

We recommend range managers monitoring forage availability for bighorn sheep use the modified Robel pole as a tool in the southern Black Hills. The relationship of visual obstruction (VOR) to herbage weight was developed as a tool to monitor available herbage for bighorn sheep. Resource categories developed provide useful guidelines for management of standing herbage to meet objectives and we recommend the intermediate category (1310 – 1787 kg/ha herbaceous biomass) as an objective. Wildlife managers can relate to short, intermediate and tall VOR categories to maintain current management direction or develop new objectives to achieve desired needs for bighorn sheep. It gives wildlife managers a fast, easy to use, accurate and cost effective technique for monitoring foraging resources within the habitat of bighorn sheep and making resource management decisions.

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White-Tailed Deer Habitat and Winter Diets in the Black Hills, South Dakota

Daniel W. Uresk, USDA-Forest Service, Rapid City, South Dakota 57701

Donald R. Dietz (Deceased), USDA-Forest Service, Rapid City, South Dakota 57701

Abstract

The purpose of this study was to determine available plant production, gain a better understanding of white-tailed deer (*Odocoileus virginianus*) diets from rumen contents and to determine the relationship between availability of plants and diets during winter months. This study was conducted in the Black Hills of South Dakota in two areas, Experimental Forest and McVey Burn. Available plant production was collected on the McVey burn during 1972-1973 and one year in the Experimental Forest in 1981, on 14 m^2/ ha basal area, representative of Forest Management. Microhistological analysis of white tailed deer rumens was used to identify and quantify diets by plant species and life forms. Deer diets on the Experimental Forest consisted of 63 percent shrubs, 22 percent graminoids and 6 percent forbs. Diets of deer on the McVey Burn were similar with 59 percent shrubs, 14 percent graminoids, and 12 percent forbs. For both study areas, five common species comprised the greatest portion of deer diets. Key forage species were prairie sagewort (*Artemisia frigida*), willow (*Salix species*), kinnikinnick (*Arctostaphylos uva-ursi*), ponderosa pine (*Pinus ponderosa*), and bluegrasses (*Poa species*). Shrubs were the most important food items in deer diets. Future habitat management efforts should be directed toward improving shrub production for white-tailed deer winter consumption. Similarity indices ranged from 0 to 88 percent, an indication that some plants were highly selected or avoided by deer (low similarities) and other plants were consumed in similar proportions as available on both areas. Rank order correlations were low and ranged from r = -0.22 on the Experimental Forest to r = 0.11 indicating white-tailed deer were not selecting plants in the same proportions as their availability.

Key words: habitat, forest, burn, grazing, herbage, forage, white-tailed deer

Introduction

White-tailed deer (*Odocoileus virginianus*) represent a valuable resource in the Black Hills of South Dakota. Total annual harvest approximates 4,000 to 5,000 animals and has generated millions of dollars in revenue in license fees in South Dakota (Petersen 1984). Total harvests of white-tailed deer from 2005 through 2014 ranged from 2,410 in 2014 to a high of 5,397 animals in 2007 with a mean 3,085 over a 10 year period (SDGFP 2017). It is estimated that the Black Hills white-tailed deer hunting season generates over $2 million dollars annually to the economy (Deperno et al. 2002).

In the Black Hills area white-tailed deer populations have been in steady decline during the past few decades (Petersen 1984: Deperno et al. 2002). Several theories have been advanced as explanations of this downward trend in recent years including degradation of habitat primarily from heavy livestock grazing, interspecific competition with elk (Wydeven and Dhlgren 1983; Uresk et al. 2007; Uresk et al. 2009a; Uresk et al 2009b; Mergen 2013), and habitat loss due to land development. Average cattle diets in the Black Hills for both shrub and tree consumption combined ranged from 20 percent to 37 percent in the northern Black Hills and and from 8 percent to 35 percent in the central Black Hills (Uresk and Lowery 1984; Uresk and Paintner 1985; Uresk 1987). Livestock grazing management has remained essentially static since 1982 through 2005 with Forest Plans (USDA Forest Service 1983; USDA Forest

Service 1997; USDA Forest Service 2005) based on standards and guidelines, although some allotment management plans changed yearly. Elk diets in Wind Cave National Park focused primarily on graminoids with forbs the most important forage class for the fall and winter periods (Wydeven and Dhlgren 1983). Browse species (e.g., shrubs) were minor components of the elk diets. However, elk were not present in the area when this study was conducted, only in later years.

Forage, water and cover are the primary habitat components that limit deer populations and loss and degradation of habitat is the most important single factor in decline of deer populations (Deperno et al. 2002). As habitat is lost and/or degraded, deer forage and cover is quantitatively and qualitatively decreased, resulting in malnutrition, starvation, and poor reproductive success.

White-tailed deer in the Black Hills, especially those from the McVey Burn area, are more migratory than those found in other areas and have distinct winter, spring and summer-fall ranges (Thilenius 1972; Deperno et al 2002). Although summer range is important and in some cases critical, winter habitat and forage is the key factor limiting deer populations in the West (Wallmo et al. 1977; Deperno et al. 2002). Tall-growing palatable shrubs, which provide forage when other short statured forages are unavailable due to snow cover or of poor nutritional quality, are one of the most important components on winter range and are in many cases lacking or seriously depleted in the Black Hills. A further ecological review of the white-tailed deer in the Black Hills is presented by Sieg and Severson (1996).

The objective of this study is to compare early, mid and late winter white-tailed deer diets and forage production on two different study areas within the Black Hills (McVey Burn and Experiment Forest). Results from this research will hopefully aid in future monitoring and management for white-tailed deer in the Black Hills.

Study Area

The Black Hills encompasses about 5001 km^2 (USDA-Forest Service 1983) and is approximately 193 km from north to south, beginning in the northeastern portion of Wyoming and following the western most border of South Dakota. The elevation within the study areas ranges from 1600 m to 1800 m. Precipitation during the study period compared to recent precipitation data show no significant changes. During the study period, average annual precipitation on this area was about 51 cm and 80% falls from April to September (Dietz et al 1980). Current average annual precipitation at Hill City, SD is 53 cm, of which 79 percent falls from April to September (CLIMOD 2 2016). The growing season is approximately 89 days and average annual temperatures range from -6.2^0 C to 35.5^0 C.

This study was conducted on two sites within the Black Hills: 1) the Black Hills Experimental Forest, which has an overstory of mature trees, and 2) the McVey Burn Area which was dominated with ponderosa pine (*Pinus ponderosa*) with few open meadows prior to a forest fire in 1939 and subsequently was dominated with immature ponderosa pine during the study period (Dietz et al. 1980). The Experimental Forest is located approximately 32 km (20 miles) west of Rapid City and is dominated by ponderosa pine. Understory shrubs for the Experimental Forest include kinnikinnick (*Arctostaphylos uva-ursi*), chokecherry (*Prunus virginiana*), creeping barberry (*Mahonia repens*), Saskatoon serviceberry (*Amelanchier alnifolia*) and common snowberry (*Symphoricarpos albus*). Common graminoids include roughleaf ricegrass (*Oryzopsis asperfolia*), timber oatgrass (*Danthonia intermedia*), sedges (*Carex species*), Kentucky bluegrass (*Poa pratensis*), cream pea (*Lathyrus ochroleucous*) and bluebell bellflower (*Campanula rotundifolia*). Hoffman and Alexander (1987) describe habitat types and plant species throughout the Black Hills.

The McVey Burn located northwest of Hill City in the central Black Hills, South

Dakota comprises about 8903 ha that burned from a wildfire in 1939 (Dietz et al. 1980). Prior to the fire, the area was dominated by mature ponderosa pine with a few small meadows. Over 60 percent of the area was burned. This area was utilized by white-tailed deer primarily during the winter and was one of the most important winter deer ranges in the Black Hills. Native vegetation consists of Saskatoon serviceberry Woods' rose (*Rosa woodsii*), little bluestem (*Schizachyrium scoparium*), prairie sagewort (*Artemisia frigida*), common snowberry, and Kentucky bluegrass.

Methodology

Vegetation Production

Herbage production was determined on the Experimental Forest site within sapling stands (14 m^2/ha basal area) on three replicated plots during August, 1974 (Uresk and Severson, 1998). Six randomly placed transects 15 m in length were placed within each of the three plots. Twelve 30 x 60 cm quadrats were randomly placed along each transect. The current annual herbage growth was harvested at ground level for each herbaceous species. All leaves, and the terminal portions of twigs to the first node, were clipped on each shrub. Plant material was oven dried at 60^0 C for 48 hours and oven dry weights obtained. Weights were averaged and expressed as means per plot for data analyses.

On the McVey Burn, visual estimates and clipped standing herbage were sampled by species at peak production from July - August during 1972 and1973 from two randomly selected plots each year. Using the weight-estimated method described by Pechanec and Pickford (1937), herbage yields were obtained by species using a ratio estimator. Each plot was 30.5 m by 30.5 m. Ten circular hoops (0.89m^2) were placed on each of four transects spaced 3 m apart for a total of 40 clipped hoops. Visual estimates by plant species (green weight by ounces) were obtained within all 10 circular hoops for each transect. One circular hoop on each transect was randomly selected for clipping herbage at ground level by species. All leaves and terminal portions of twigs to first node were clipped on shrubs and visually estimated. All plant material by species was oven dried at 60^0 C for 48 hours and corrected to oven dry weights. The ratio estimator by species = mean of actual clipped weights (oven dried) / mean of estimated weights was used for a correction factor. The correction factors by species were multiplied for each visually estimated species within all hoops per plot. Mean weights per plot (replicate) were used for analyses.

Deer Diets

Data on deer diets were compiled by microhistological examination of rumen contents from 17 deer harvested directly on the Experimental Forest over five winters, and from 40 deer harvested on the McVey Burn Area during five winters (December-May). McVey burn was a wintering area for many deer while in the experimental forest few deer remained in the area during winter months. With fewer deer in the experimental forest, harvesting deer was much more difficult, resulting in different numbers of deer harvested in the two areas. Deer were collected in 1967, 1969, 1970, 1971 and 1972 for both areas. Rumen samples from each deer were kept frozen prior to examination. Individual samples were then thawed, dried, and ground through a Wiley mill fitted with a 1 mm screen. All rumen material was washed over a 0.1-mm screen (Sparks and Malechek 1968). Rumen material was cleared of chlorophyll and other composites with Hertwig's solution. Microhistological examinations of the samples were conducted using standard procedure with 5 slides per rumen sample and 20 fields per slide under a binocular microscope at 100 power for identifiable plant fragments (Sparks and Malechek 1968; Rogers and Uresk 1974; Johnson et al 1983). Hand compounded test mixtures of plants were used periodically to check accuracy of reading slides for plant identification and to maintain quality control. A similarity of 90 percent was maintained between actual test

mixtures of plants and estimated values of plants read from slides (Rogers and Uresk 1974).

Statistics

Data from microhistological examination of rumen contents were reported as percentages of dietary density. Changes by forage categories in monthly diets of white tailed deer were analyzed using one-factor analysis of variance (SPSS 2003). The F-protected Tukey's Multiple Range Test ($p \leq 0.10$) was used to perform comparisons among months.

Vegetation production data for each species and category (shrub, forb, grass, and tree) were averaged across years on the McVey Burn site (n=4). Vegetation production collected in 1974 comprised the data for the Experimental Forest site (n =3).

Kulczyuski's similarity index (Oosting 1956) was used to compare deer diets with herbage production to determine degree of association. Spearman's rank order correlation (SPSS 2003) was used to compare the relationship of herbage production with deer diets.

Results

Vegetation Production - Experimental Forest

Total plant production on the Experimental Forest averaged 557 kg/ha (Table 1). Shrubs accounted for the greatest amount (55%) of production with 308 kg/ha and more specifically, kinnikinnick provided 293 kg/ha. Others shrubs included American red raspberry (*Rubus idaeus*) with 5 kg/ha, Woods' rose (4 kg/ha) and common snowberry with 4 kg/ha.

Graminoid phytomass was 212 kg/ha (Table 1), 38 percent of the total production. Roughleaf ricegrass provided 124 kg/ha, followed by timber oatgrass at 47 kg/ha, sedges at 25 kg/ha, and bearded wheatgrass (*Elymus caninus*) with 7 kg/ha. Other minor grass species were mountain ricegrass (*Piptatheropsis pungens*) at 3 kg/ha and bluegrasses at 5 kg/ha.

Forbs were the least productive (7%) with 37 kg/ha. Milk vetch (*Astragalus species*) yielded 13 kg/ha followed by cream pea with 12 kg/ha (Table 1). Other forbs included common yarrow (*Achillea millefolium*), field pussytoes (*Antennaria neglecta*) and woodland strawberry (*Fragaria vesca*) (1-4 kg/ha).

Vegetation Production - McVey Burn

Vegetative production on the McVey Burn area averaged 684 kg/ha (Table 1). Shrubs accounted for the majority of vegetation (60%) with 408 kg/ha. Among shrub species, mountain ninebark (*Physocarpus monogynus*) yielded 151 kg/ha, russet buffaloberry (Shepherdia canadensis) at 105 kg/ha, Woods'rose at 64 kg/ha, common snowberry at 31 kg/ha, and white spirea (*Spiraea betulifolia*) at 29 kg/ha were the most abundant. Minor species accounted for an additional 26 kg/ha of production. Woody species present in the area but not sampled included quaking aspen (*Populus tremuloides*), prairie sagewort, creeping barberry, common juniper (*Juniperus communis*) and chokecherry.

Grasses and forbs accounted for approximately 20 percent of the production each. Grasses provided 143 kg/ha, of vegetative production (Table 1). Canada wildrye (*Elymus canadensis*) produced 106 kg/ha, followed by bluegrasses (*Poa species*) at 21 kg/ha, and sedges at 5 kg/ha. Forbs averaged 135 kg/ha (Table 1). Important forbs included asters at 37 kg/ha, American licorice (*Glycyrrhiza lepidota*) at 21 kg/ha, northern bedstraw (*Galium boreale*) at 19 kg/ha, spreading dogbane (*Apocynum androsaemifolum*) with 18 kg/ha, and cinquefoils (Potentilla species) at 12 kg/ha.

Deer Diet - Experimental Forest

Shrubs were the most important component in diets of deer collected on the Experimental Forest throughout the three sampling periods- early winter (December-January), mid-winter (February-March) and late winter-spring (April-May) (Table 2, Fig. 1). Shrubs were common in white-tailed deer diets during the winter (December-May) comprising 63 percent of the diet (Table 3). Kinnikinnick was the most

Table 1. Average plant production (Kg/ha ± SE) on the Experimental Forest (14 m2/ha basal area, Uresk and Severson (1998))[1] and McVey Burn in the Black Hills, South Dakota.

Category	Experimental Forest[1] (n = 3) 1974	McVey Burn (n = 4) 1972-1973
Forbs		
Actaea rubra	0	3 ± 2
Achillea millefolium	2 ± 1	4 ± <1
Antennaria neglecta	1 ± 1	<1
Apocynum androsaemifolium	0	18 ± 7
Symphyotrichum ciliolatum	0	17 ± 4
Aster spp.	0	8 ± 7
Astragalus spp.	13 ± 6	0
Fragaria vesca	4 ± 3	3 ± 2
Galium boreale	0	19 ± 3
Glycyrrhiza lepidota	0	21 ± 13
Lathyrus ochroleucus	12 ± 7	12 ± 5
Potentilla spp.	0	12 ± 7
Solidago spp.	0	3 ± <1
Taraxacum officinale	0	5 ± 1
Vicia americana	0	10 ± 4
Other species	5	1
Total Forbs	**37 ± 14**	**135 ± 23**
Graminoids		
Agropyron caninum	7 ± 4	0
Bromus spp.	0	4 ± 2
Carex spp.	25 ± 5	5 ± 1
Danthonia intermedia	47 ± 2	0
Elymus canadensis	0	106 ± 18
Oryzopsis asperifolia	124 ± 88	0
Piptatheropsis pungens	3 ± 3	0
Poa spp.	5 ± 5	21 ± 9
Other species	1	7
Total Graminoids	**212 ± 91**	**143 ± 51**
Shrubs		
Arctostaphylos uva-ursi	293 ± 78	1 ± 1
Physocarpus monogynus	0	151 ± 36
Rosa woodsii	4 ± 3	64 ± 7
Rubus idaeus	5 ± 4	1 ± 1
Shepherdia canadensis	0	105 ± 21
Spiraea betulifolia	0	29 ± 8
Symphoricarpos albus	4 ± 3	31 ± 6
Other species	2	26
Total Shrubs	**308 ± 76**	**408 ± 89**
GRAND TOTAL	**557 ± 138**	**684 ± 113**

important shrub utilized. Consumption of kinnikinnick increased to a high of 59 percent in late winter with an overall winter average of 41 percent. Willow (*Salix species*) made up 13 percent of the winter deer diet (Table 3). Common juniper (*Juniperus communis*) was 5 percent of the overall diet. Other shrubs were minor components in deer diets.

Grass presence within the overall deer diets ranged from 17 to 36 percent (average of 22 percent) (Table 2 Fig. 1). Bluegrasses (*Poa species*) were the most common graminoid utilized. (Table 3). Needle-and-thread (*Hesperostipa comata*) including green needlegrass (*Nassella viridula*) provided 3 percent of the winter diet (Table 3).

Forbs were less commonly found in diets throughout winter, ranging from 2 to 7 percent (Table 2). Field pussytoes and cinquefoils were common forbs in the diets (Table 3). Lichen comprised 2 percent during the winter months. Trees were of limited importance with 4 percent.

Table 2. White-tailed Deer Diets (% ± SE) by Plant Category for the Experimental Forest and McVey Burn in the Black Hills, South Dakota.

	Forest			Burn		
Category	**Early Winter Dec-Jan n=5[1]**	**Mid-Winter Feb-Mar n=8**	**Late Winter Apr-May n=4**	**Early Winter Dec-Jan n=6**	**Mid-Winter Feb-Mar n=19**	**Late Winte Apr-May n=15**
Forbs	7.2 ± 0.7bd[2]	2.4 ± 0.3cd	5.6 ± 1.2d	13.5 ± 1.0a	8.0 ± 0.2b	13.9 ± 0.2a
Graminoids	17.4 ± 2.0c	17.6 ± 2.8bc	36.3 ± 3.0a	17.0 ± 3.7c	5.5 ± 0.1d	23.4 ± 0.7b
Lichen	3.6 ± 1.1a	1.4 ± 1.1b	1.5 ± 1.5b	0.2 ± 0.2b	0.2 ± 0.2b	0.2 ± 0.1b
Shrub	65.2 ± 2.5b	75.0 ± 3.0a	32.5 ± 3.1d	50.7 ± 3.0c	69.9 ± 1.4ab	49.1 ± 1.2c
Trees	6.8 ± 3.1abc	3.3 ± 2.0bc	2.0 ± 0.9c	18.8 ± 15.8a	17.1 ± 5.6a	3.5 ± 4.5ab

[1] Rumen sample size

[2] According to Tukey's Test, means in a row followed by a similar letter are not significantly different at p ≤ 0.10.

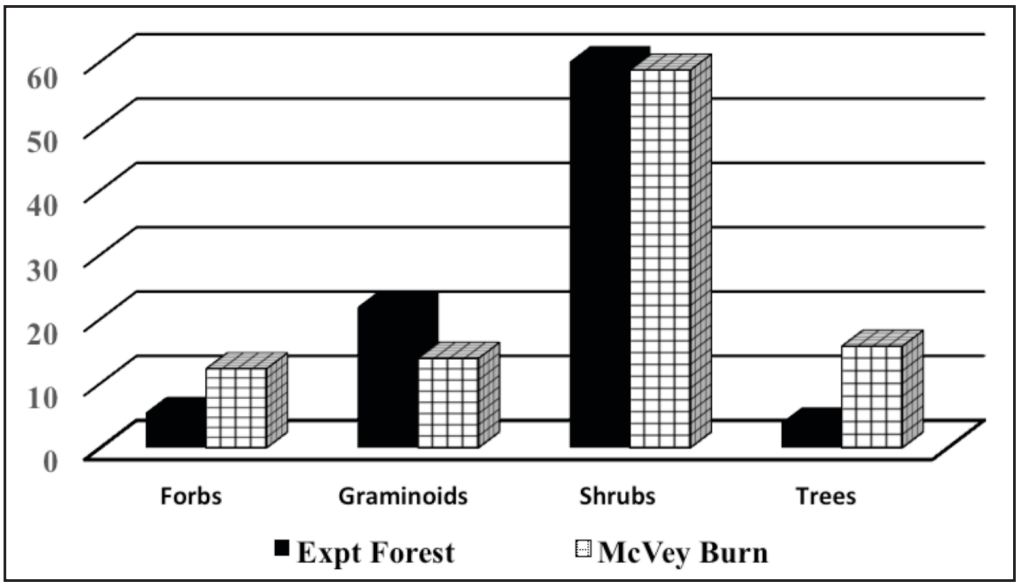

Figure 1. White-tailed deer diets (%) during winter months (December – May) by plant category on the Experimental Forest and McVey Burn.

Table 3. Mean winter deer diets (%) by plant species on the Experimental Forest and McVey Burn in the Black Hills, South Dakota.

Winter White-tailed Deer Diets (December-May)		
Plant Species	**Experimental Forest (n = 17)[1]**	**McVey Burn (n = 40)**
Forbs		
Antennaria neglecta	3.3	2.9
Astragalus spp.	0.2	2.7
Potentilla spp.	1.8	2.5
Solidago spp.	0.2	4.2
Total Forbs	**5.5**	**12.3**
Graminoids		
Carex spp.	1.8	2.5
Danthonia intermedia	0.1	1.8
Poa spp.	7.2	9.4
Hesperostipa comata+Nassella viridula	2.8	0.2
Total Graminoids	**21.9**	**13.9**
Unknown lichen	**2.1**	**0.5**
Shrubs		
Arctostaphylos uva-ursi	40.5	1.6
Artemisia frigida	0	35.9
Mahonia repens	3.7	0
Juniperus communis	4.6	0.5
Rosa woodsii	0.3	1.0
Rubus idaeus	0.5	2.2
Salix spp.	12.6	14.8
Shepherdia canadensis	1.2	2.7
Total Shrubs	**63.4**	**58.7**
Trees		
Pinus ponderosa	**3.9**	**15.8**

[1] Rumen sample size

Deer Diet - McVey Burn

Shrubs were the most abundant among all deer diet categories on the McVey Burn (Table 2, Fig. 1). Shrubs in deer diets ranged from 49 percent to 70 percent and were highly important throughout December-May. Prairie sagewort was common constituting 36 percent of the diet (Table 3). Willows comprised 15 percent of the diet. Other shrubs included kinnikinnick and American red raspberry with 2 percent and russet buffaloberry with 3 percent of the diet.

Graminoids were more dominant in deer diets during early winter (17%) and early spring (23%) (Table 2). Bluegrasses comprised 9 percent of the diet (Table 3). Other graminoids (2-3%) included timber oatgrass and sedges.

Forbs were significant during early winter and late winter with 14 percent of the deer diet, decreasing to 8 percent mid-winter (Table 2). Goldenrod (*Solidago species*) provided 4 percent of the diet (Table 3). Field pussytoes, milk vetch and cinquefoils were minor (2-3%) components in the

diet. Lichens were insignificant in diets. Ponderosa pine needles provided 16 percent of the deer diet (Table 3). Other tree species in the diets were not observed.

Deer Diet - Experimental Forest vs McVey Burn

Shrubs in deer diets on the Experimental Forest and McVey Burn were similar during the winter season (December through May) with each comprising approximately 60 percent of the total diet (Table 3, Fig. 1). Major shrubs in diets included kinnikinnick and willow on the Experimental Forest with fringed sage and willow on the McVey Burn (Table 3). Graminoids were the second most abundant forage plants in deer diets with 22 percent and 14 percent of the total diets on the Experimental Forest and McVey Burn areas, respectively (Table 3, Fig. 1). Forbs were the least abundant forage plants in the deer diets with 6 percent on the Forest and 12 percent on the Burn (Table 3, Fig 1).

Ponderosa pine needles made up approximately 16 percent of the total deer diet on McVey Burn (Table 3, Fig 1). Trees were small in stature on this site (Dietz et al. 1980). White-tailed deer diets on the Experimental Forest consisted of fewer pine needles within the diet with 4 percent. The area had larger and more mature pine trees. Both areas had a decreasing trend in trees observed in the diet from early to late winter (Table 2).

Relationships between Available Forage Species and Deer Diets

Percent similarity between available herbage and white-tailed deer diets ranged from 0 to 88 percent. High similarities indicate that deer are selecting specific plant species or groups in the same proportions as available in the areas. Low similarities show that deer are avoiding plants for food. Similarity indices for forbs, graminoids and shrubs were greater on McVey Burn than for deer associated in the Experimental Forest area. Spearman's rank order correlations were low for both study areas. These relationships of available herbage vs deer diets on the Experimental Forest were, r = -0.22 and McVey Burn, r = 0. 11. Correlations of each area were not significant at $p \leq 0.10$. This indicates that white-tailed deer were not selecting plants for their diet in the same proportions as their availability on both areas.

Discussion

The Black Hills are dominated with widely distributed ponderosa pine. It is the major climax species in 7 of the 12 habitat types described by Hoffman and Alexander (1987). The study areas were in a *Pinus ponderosa/Arctostaphylos uva ursi* habitat type. During late fall and early winter months white-tailed deer would migrate to the McVey Burn primarily for forage availability. White-tailed deer on the Experimental Forest were yearlong residents. Plant production on the Experimental Forest with ponderosa pine at 14 m^2/ha basal area (saplings) was used to compare with the McVey Burn area (Uresk and Severson 1998). Plant species richness was greatest on the Burn area, however the number of plant species in white-tailed deer food items were similar with 17 species for each area during the months December through May. Shrubs were the most important food items in white-tailed deer diets during the winter months for both areas. Hill and Harris (1943) reported 65 percent of white-tailed deer diets in the Black Hills consisted of 23 shrub and tree species during October- December and 21 shrub and tree species from January- April from rumen contents. In comparison, this study identified 9 shrubs and trees in white-tailed deer diets pooled for both sites, a significant decrease in shrub species. This may be due to a reduction in shrub species over a 29 year period due to management of the resources or differences in areas surveyed.

Kinnikinnick was by far the most important shrub species in the diet of white-tailed deer on the Experimental Forest site, comprising as much as 59 percent of the diet in winter. Hill and Harris (1943) reported that kinnikinnick made up 24 percent of

the white-tailed deer diet during the winter months. This species is one of the most important browse species during winter on ponderosa pine sites in the Black Hills (Hill and Harris 1943) and is the most productive shrub on many sites (Pase 1958; Uresk and Severson 1998). It is highly digestible and has a high intra-cellular carbohydrate and mineral content (Uresk et al. 1975). The importance of kinnikinnick, and its high preference value in winter has been demonstrated in other studies of white-tailed deer (Schneeweis et al. 1972; Hill and Harris1943). Conversely, kinnikinnick was a conspicuously minor element in the diets of deer collected on the McVey Burn Area with a high of 8 percent in early winter. Production for kinnikinnick on the McVey Burn was low, however, this species has a high association with the ponderosa pine forest.

Prairie sagewort was important in deer diets on the McVey Burn. This species will maintain a high digestibility of 60 percent throughout the winter while other woody species decrease markedly through winter months (Dietz 1972). Prairie sagewort is high in energy, partially due to the presence of large amounts of essential oils (Dietz 1972).

Ponderosa pine needles comprised a high proportion of the winter diets of deer on the McVey Burn Area. Pine needles are a palatable deer food and there has been some concern about pine needle abortion with deer but no supportive information. The predominance of pine needles in winter diets of deer on the McVey Burn Area may have been influenced by snow cover and temperature, although the high percentage of short statured prairie sagewort in diets, suggests there was little or no snow cover in some areas of the burn.

Willows were important in deer diets on both areas for the winter months. On the Experimental Forest willow comprised 30 percent of the diet during early winter (Uresk, unpublished data), a time of high utilization. Willow was consistently found in deer diets throughout the winter season at approximately 13 percent in the Forest and 15 percent on the McVey Burn. Willow is considered a relatively high protein forage (Dietz 1965). Willows are important browse plants throughout the Black Hills and for stabilizing stream banks, and providing shade to lower stream temperatures. However, over-browsing and trampling of the riparian systems and loss of willows has been primarily attributed to livestock, although disease and insects are some causative factors (Froiland 1962). Current willow surveys are not available but observations of willows in the Black Hills indicate heavy use and trampling by livestock.

Graminoids were commonly used by deer in both study areas, during early winter and spring. Hill and Harris (1943) reported similar results. Cook (1972) reported that bluegrasses are high in nutritive value early in the spring, but lose their nutritive value rapidly during active growth. Cool season grasses (needle grasses) start growth later but retain their nutrients with maturity.

While forbs were common components of deer diets throughout the winter months, they were more important in the diets of deer on the McVey Burn. Forbs are low in nutritional qualities during the winter and generally do not furnish adequate nutrients after fruiting stage (Cook 1972). However, forbs are a common component of deer diets in the Black Hills, but are not considered high nutritional value food items (Hill and Harris 1943; Dietz 1972).

Several forage species with high similarity indices include Solidago species, bluegrass, kinnikinnick, sedges and American red raspberry in the McVey Burn. High similarities in the Experimental Forest included field pussytoes, while other plant species exhibited low similarities. White-tailed deer consuming forage plants in approximately the same proportions as available are considered high similarities. Overall, the rank order correlations relating availability of plants to deer diets, indicated that deer were not selecting food items in the same proportions as availability.

These selective differences are attributed to digestibility and nutrients of the various forage species (Dietz 1972).

Winter use of forage categories by white-tailed deer on both sites followed similar trends found in other studies, with grasses and forbs most important in late winter and spring, shrubs and forbs most important in fall, and shrubs most important in winter (Schneeweis et al. 1972; Hill and Harris1943). In this study, shrubs were an important food component in white-tailed deer diets on both sites. Fewer shrub species occurred in deer diets from the Experimental Forest and McVey burn than reported by Schneeweis et al. (1972). More recently, the reduction in shrub and tree species in deer diets has been attributed to heavy utilization of shrubs by livestock and wildlife (Uresk and Lowry 1984; Uresk and Painter 1985; Hoffman and Alexander 1987; Deperno et al. 2000; Deperno et al. 2002).

Management Implications And Summary

Although these data were collected over 35 years ago, the data provided on forage production and winter diets of white-tailed deer diets provides new and additional information that has not been published. This study is helpful and informative to managers with respect to white-tailed deer habitat needs. Winter deer diets on the Experimental Forest and McVey Burn were similar. Important forage species were prairie sagewort, willows, kinnikinnick, ponderosa pine and bluegrasses. Shrubs were the most preferred food items consumed by white-tailed deer during winter months. Methods to improve shrub production and other plant diversity and/or quantity are available (Sieg and Severson 1995; Dietz et al. 1980; Uresk and Severson 1998) and include optimizing tree density for shrub production by controlled burning geared to stimulation of shrub enhancement in the forest and planting of shrubs in key deer wintering areas. In addition, management of livestock grazing at acceptable levels leaving 60% of herbage left ungrazed (based on modified Robel pole and visual obstruction of herbage (0.5-inch bands) at average peak herbage) will provide increased benefits for improvement of plant resources for quantity and diversity (Beetle et al. 1961; Severson and Urness 1994: Uresk and Benzon 2007; Uresk et al. 2009a, 2009b; Juntti 2012; Mergen 2013). The benefits of leaving adequate residual herbage, approximately 60 percent of average peak herbage left ungrazed are: 1) increase plant diversity and production, 2) decrease soil temperature and increase soil moisture, 3) reduce runoff of water, and 4) plants mature later and are healthier. Leaving adequate levels of residual vegetation throughout the rangelands including dry years in the Black Hills will provide for increased shrub diversity and availability, improving the resources for livestock and wildlife. Such measures would greatly enhance winter deer range and lend support to a declining deer population ((Deperno et al. 2000; Deperno et al. 2002, SDGFP 2017).

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Effects of Livestock Grazing and Cultural Treatments on Regeneration of Green Ash Woodlands on the Northern Great Plains: An Update

Daniel W. Uresk, USDA Forest Service, Rapid City, SD. 57701.

Daryl E. Mergen, Ecological Delineations, Inc., Colorado Springs, CO 80905

Abstract

Many green ash woodlands (*Fraxinus pennsylvanica*) have become decadent with broken stems and limited regeneration of both trees and shrubs on the northern Great Plains. The purpose of this study was to determine the response of woodland regeneration of shrubs, trees and planting woody species over 25 post-treatment years (1) to livestock grazing with thinning low vigor trees, (40% reduction) in woodlands with transplanting woody plants, (2) livestock grazing with un-thinned woodlands-no transplanting of woody plants, (3) no livestock grazing with thinning low vigor trees, (40% reduction) in woodlands with transplanting woody plants, and (4) no livestock grazing with un-thinned woodlands-no transplanting of woody plants. Initial treatment response for trees and shrubs occurred during the first 6 years of post-treatment. After 25 years of post-treatment, trees and shrubs were not different between livestock grazing and no grazing treatments. American elm (*Ulmus americana*) decreased in stem density and may have been influenced by disease. Stem density of snowberry (*Symphoricarpos occidentalis*) decreased in the unthinned treatment. Common chokecherry (*Prunus virginiana*) stem densities remained relatively constant over 25 years of post-treatments. Planted shrub and tree species had greater than 50% survival in ungrazed versus grazed treatments. Survival of bur oak (*Quercus macrocarpa*), Rocky Mountain juniper (*Juniperus scopulorum*) and American plum (*Prunus americana*) was greater when livestock grazing was excluded. Herbaceous standing crop of the grasses, forbs, and total was variable throughout all years among treatments.

Key Words: green ash, decadent trees, thinning, herbage, prairie, regeneration, plantings, livestock grazing.

Introduction

Green ash (*Fraxinus pennsylvanica*), riparian-like woodlands, are generally confined to draws or ravines that have ephemeral streams on the Northern Great Plains. They occupy less than 1% of the land on the plains (Jakes and Smith 1982). However, many green ash woodlands have become decadent with low vigor, little or no regeneration, and dying or partially dead trees. These woodland systems have poor reproduction of trees, shrubs, and many are overgrazed being replaced by grasses and forbs (Severson and Boldt 1978, Boldt et al. 1978, Lesica and Marlow 2013). Although restoration of these decadent woodlands is a slow process, some shrubs and green ash trees will respond to cultural treatments by reversing decadence (Uresk and Boldt 1986, Lesica 2009). Small in area, green ash woodlands are very important for livestock and wildlife providing food and cover, including nesting cover, for birds during summer months and protection during the winter (Severson and Boldt 1978, Bjugstad and Sorg 1985, MacCraken and Uresk 1984, Butler and Goetz 1984, Hodorff et al. 1988, Rumble and Gobeille 1998, Lesica and Marlow 2013).

Livestock grazing can result in decreased plant vigor and alteration of plant communities and species composition (Garrison 1953, Willard and McKell 1978,

Ellison 1960), however, it may be just one of many factors that impact prairie woodland regeneration. Bolt et al. (1978) and Severson and Boldt (1978) reported many shrub-tree stands are degenerating because they are near the end of their lifespan. Older trees may also be more susceptible to disease, insects, and grazing (Lesica and Marlow 2013). The construction of stock ponds, roads, climate, geology, soils, plant succession, and wildfire suppression may be other factors that influence the long-term changes in prairie woodlands.

The objectives of this study were to determine the vegetation response of regeneration to four cultural treatments for trees, shrubs, and herbaceous standing crop on the northern Great Plains over 25 post-treatment years (1) to livestock grazing with thinning low vigor trees (40% reduction) in woodlands with transplanting woody plants, (2) livestock grazing with un-thinned woodlands-no transplanting of woody plants, (3) no livestock grazing with thinning low vigor trees, (40% reduction) in woodlands with transplanting woody plants, and (4) no livestock grazing with un-thinned woodlands-no transplanting of woody plants (Uresk and Boldt, 1986).

Study Area

This study was located on the Little Missouri National Grasslands, Dakota Prairie Grasslands, in western North Dakota. The green ash woodlands were selected in the upper reaches of Magpie Creek Drainage 41.8 km (26 miles) north of Belfield. Climate is cool-temperate, semi-arid with variable precipitation and temperatures. Average precipitation from 1981-2010, at Grassy Butte, ND (Grassy Butte 2ENE), approximately 12.9 km (8 miles) north of the study area was 41cm (16.2 inches) (Climod 2 2016). Average growing season temperature from April to September was 15.2^{0}C (59.3^{0}F); winter temperature (October-March) averaged -3.1^{0}C (26.4^{0}F). Dominant trees within the selected woodlands were green ash and American elm (*Ulmus americana*). The shrub understory included western snowberry (*Symphoricarpos occidentalis*), Wood's rose (*Rosa woodsii*), spiny currant (*Ribes setosum*), Saskatoon serviceberry (*Amelanchier alnifolia*), silver buffaloberry (*Shepherdia americana*), common chokecherry (*Prunus virginiana*), American plum (*Prunus americana*), hawthorn (*Crataegus* spp.), and raspberry (Rubus spp.). Common grass and grass-like species included Kentucky bluegrass (*Poa pratenensis*) and sedges (*Carex* spp.) (Boldt 1978). Plant nomenclature followed USDA-NRCS (2016).

We selected green ash study areas located in two pastures grazed by cattle in a three pasture allotment under a deferred rotation grazing system. Stocking rate was 1.07 AUMs/ha (animal unit months) from May 15 to October 30. This area had been grazed season long as a single pasture prior to establishing a three pasture deferred rotation grazing system. The selected pastures were in the deferred grazing system two years before initiation of the study (Uresk and Boldt 1986).

Methods

We selected twelve sites, 0.08 ha, for sampling within several green ash draws (Boldt et al. 1978). The study included four treatments (1) livestock grazing with thinning low vigor trees (40% reduction) in woodlands with transplanting woody plants, (2) livestock grazing with un-thinned woodlands-no transplanting of woody plants, (3) no livestock grazing with thinning low vigor trees, (40% reduction) in woodlands with transplanting woody plants, and (4) no livestock grazing with un-thinned woodlands-no transplanting of woody plants. Herbaceous standing crop of grasses (including sedges), forbs, and total was harvested within the four treatments. The four treatment combinations were randomly administered among the 12 sample sites with 3 replications per treatment. Fences to exclude cattle were constructed by the fall of 1975.

Pretreatment and post-treatment measurements were collected during the end of the growing season each year.

Pretreatment measurements were collected in 1975 and post-treatment measurements were collected for shrubs, small trees on all sites for six subsequent years (1976-81) and in 2001, 26 years after initial installment of treatments. Small trees (less than 2.5 cm Diameter Breast Height (DBH)) and shrubs stem and heights were measured by species on five randomly located 15.3 by 1.2 meter belt transects (18.4 m^2) within each sample site.

Sites selected for tree removal were selectively cut to 40% of total tree stems to open the canopy and stimulate sprouting in 1975 (Boldt et al. 1978). Decadent trees with low vigor (rotten, broken, and poorest of the growing stock as described by Boldt et al. 1978) were cut and removed from plots. Tree species composition on each of the 12 sites was determined before and after tree removal. Decadent trees from each cut site were randomly selected and number of sprouts per stump and height of sprouts each year were measured.

We planted containerized tree and shrub seedlings on the thinned tree sites in spring of 1977 (second post-treatment year). Green ash, Rocky Mountain juniper (*Juniperus scopulorum*), bur oak (*Quercus macrocarpa*), common chokecherry, American plum, and Russian olive (*Eleagnus angustifolia*) were planted. Twenty-four containerized seedlings of each species were planted in each of the six partially cut woodland sites on herbicide-treated (2, 2 dichloropropionic acid) spots. All species and containerized pots were randomly distributed throughout a systematic lattice pattern with 2-3 meter spacing.

Understory herbaceous biomass estimates were obtained by clipping 20 (31-cm x 61 cm) quadrats in 1979-1981 and 20 (50 x 50 cm) quadrats in 2001. Quadrats were clipped to ground level at all 12 sites in late August. Grasses (sedges included) and forbs were separated, placed in paper bags, oven-dried for 48 hours at 60^0C and weighed to the nearest 0.1 g. Weights for grazed and ungrazed herbage were expressed as $kg \bullet ha^{-1}$.

Shrub stems and height measurements by species were averaged by site for statistical analyses. Analysis of covariance, using 1975 year's data as the covariate, was used for mean adjustment for each of the post treatment years for each species (SPSS 2003). Six years of posttreatment adjusted means were averaged between two grazing treatments and two thinned treatments. T-tests were used to evaluate differences between treatments at $p \leq 0.10$. The 25^{th} year adjusted mean of post-treatment effects of two grazing and two thinned treatments were evaluated by T-tests based on means of six sites by treatment.

We used Chi-square analysis (2 x 2) to test for differences in percent survival of shrub and tree plantings, stand composition, and stump sprouts. T-tests were used to evaluate differences between two grazing and two thinned conditions for the number of sprouts per stump, height of clump sprouts, heights of planted trees and shrubs, and herbaceous plant biomass. All significant levels were set at $p \leq 0.10$ unless stated otherwise.

Results

Stand Composition and Partial Cutting

Measurements of pre-treatment overstory consisted of 60% green ash (286 ± 37 trees ha^{-1} ± SE), 38% American elm (185 ± 67 trees ha^{-1}) and 2% other tree species (10 ± 5 trees ha^{-1}) (Uresk and Boldt 1986). Forty percent of the pre-treatment overstory tree stems were determined to be decadent and were cut. Twenty-five years post-treatment overstory consisted of 94% green ash (900 ± 158 trees ha^{-1}), 5% American elm (54 ± 13 trees ha^{-1}) and 1% box-elder (*Acer negundo*) for cut stands. Uncut stands had 97% green ash (894 ± 140 trees ha^{-1}) and 3% American elm (27 ± 9 trees ha^{-1}). Dead trees were measured in 2001(25 years post-treatment) and 78% and 55% of the dead trees were American elm for cut and uncut sites, respectively.

Tree Stump Sprouts and Height

Sixty percent of the stumps on the grazed plots produced sprouts and 96% on the ungrazed sites after 25 years. Most stumps produced sprouts the year following tree removal (Table 1). The mean number of live sprouts per stump after 25 years of post-treatment were 2 stems on grazed and 3 stems on ungrazed sites. Average heights of clumps on grazed sites were 21 dm compared to ungrazed sites with 41 dm. After 25 years post-treatment, the tallest live sprout was 41 dm shorter on the grazed sites compared to ungrazed sites (Table 1). All measured plant characteristics (Table 1) indicated a greater percentage or greater height (nearly 2 times) on ungrazed treatment compared to grazed treatment after 25 years.

Survival and Heights of Plantings

Survival was significantly greater for all planted shrubs and trees on ungrazed sites compared to grazed sites, except for Russian olive 25 years post-treatment (Table 2). Percent survival after 25 years post-treatment ranged from a low of 4% for Russian olive to a high of 51% for chokecherry on ungrazed sites. Bur oak and Rocky Mountain juniper had 35% and 31% survival, respectively. Wild plum and green ash had survival rates of 17% and 8%, correspondingly after 25 years of post-treatment on ungrazed sites. Grazed sites exhibited lower survival rates after 25 years, ranging from no survival with bur oak to a high of 19% for chokecherry. Russian olive and wild plum on grazed sites had 3% survival; green ash and Rocky Mountain juniper had 1% survival.

Stem heights were significantly taller after 25 years post-treatment on ungrazed sites compared to grazed sites for Rocky Mountain juniper, bur oak, chokecherry and Russian olive (Table 2). Russian olive (46 dm) had the greatest stem height on ungrazed sites followed by Rocky Mountain juniper (23 dm), chokecherry (16 dm), 11 dm for both green ash and bur oak, and 6 dm for wild plum. On grazed sites, stem heights were greatest for chokecherry, Russian olive and green ash, each approximately 7-8

Table 1. Tree stumps with live sprouts from one year post treatment to 25 years on grazed and ungrazed treatments (mean ± standard error) north of Belfield ND.

Category	Post-treatment year	Treatment	
		Ungrazed[1]	Grazed
% stumps with sprouts	1-1976	98 ± 2	100 ± 0
	3-1979	95 ± 2	95 ± 3
	5-1980	93 ± 4	87 ± 7
	25-2001	96 ± 3	60 ± 28
Sprouts/stump	3-1979	14 ± 1	17 ± 2
	5-1980	13 ± 1	16 ± 1*
	25-2001	3 ± <1	2 ± 1
Sprout height/stump (dm)	3-1979	11 ± 1	6 ± 2*
	5-1980	16 ± 1	6 ± 2*
	25-2001	41 ± 2	21 ± 11*
Tallest sprout/stump (dm)	3-1979	16 ± 1	9 ± 2*
	5-1980	21 ± 1	9 ± 3*
	25-2001	79 ± 4	38 ± 19*

[1] n = 6 sites/ treatment.

* Significant at $p < 0.10$

Table 2. Survival (%) and height (dm) of planted trees and shrubs on ungrazed and grazed treatments after 25 years of post- planting (mean ± standard error) north of Belfield ND.

Species	Post-planting year	Survival		Heights (dm)	
		Ungrazed	Grazed	Ungrazed	Grazed
Green Ash	3[1]	72 ± 7	38 ± 5*	4.2 ± 0.3	3.0 ± 0.3*
	25	8 ± <1	1 ± <1*	11.4 ± 6.9	7.0 ± 7.0
Rocky Mountain Juniper	5	88 ± 3	61 ± 6*	4.4 ± 0.5	3.9 ± 0.2
	25	31 ± <1	1 ± <1*	23.4 ± 1.2	1.8 ± 1.8*
Bur oak	5	82 ± 5	44 ± 6*	2.8 ± 0.4	1.2 ± 0.2*
	25	35 ± <1	0 ± 0*	11.2 ± 3.6	0.0 ± 0.0*
Chokecherry	5	65 ± <1	24 ± 3*	4.3 ± 0.5	1.6 ± 0.6*
	25	51 ± 4	19 ± <1*	5.5 ± 2.1	7.6 ± 3.8*
Wild plum	5	70 ± 10	11 ± 6*	4.6 ± 0.8	1.3 ± 0.7*
	25	17 ± <1	3 ± <1*	6.3 ± 3.7	2.3 ± 2.3
Russian olive	5	43 ± 8	28 ± 18*	4.8 ± 0.3	3.1 ± 0.5*
	25	4 ± <1	3 ± <1	45.6 ± 8.6	7.1 ± 7.1*

[1] n = 6 sites/ treatment. (post years 3-1978, 5-1980 to 25-2001).

* Significant at p < 0.10

dm tall. Wild plum and Rocky Mountain juniper both averaged about 2 dm height after 25 years post-treatment on grazed sites. All measured plant characteristics (Table 2) indicated a greater percentage survival or greater height (nearly 1.6-13 times) on ungrazed treatment compared to grazed treatment after 25 years.

Shrub and Tree Sprout Densities

Six year post-treatment averages for ungrazed compared to grazed stem densities showed significant differences for American elm, chokecherry and serviceberry (Table 3). American elm stem densities were greater than 200% on the grazed areas. Chokecherry average increase over the six years was 39% higher on the grazed sites while serviceberry showed an increase of 61% on the ungrazed treatment. After 25 years there were no significant differences between ungrazed and grazed treatments for all seven species. Details of the first 6 years of post-treatment effects by year for ungrazed, grazed, thinned and unthinned treatments are presented by Uresk and Boldt (1986). Snowberry and the spined shrubs (rose and current) increased over the past 25 years on grazed treatment compared to ungrazed. Green ash also had more stems per hectare with grazing compared to ungrazed.

Unthinned overstory treatments for stem densities of woody plants averaged over six year post-treatments were significantly less for green ash, American elm and snowberry (Table 3). Stem densities were significantly greater on the unthinned treatment for chokecherry and spiny current. Green ash densities were greater on the thinned overstory tree sites by 130% compared to the unthinned treatment. American elm increased over 300% on the thinned treatment as related to the unthinned sites. Chokecherry increased 42% on the unthinned treatment. Spiny current showed 16% increase on the unthinned areas while, snowberry exhibited a 14% decrease. After 25 years, only snowberry showed significant stem density increase with 43% on the thinned overstory treatment. Overall, (Table 3), although not significantly greater, the unthinned trees (green ash and American elm) may have done better after 25 years compared to the thinned treatments, while all shrubs increased with the thinned treatments.

Table 3. Response of woody plants within green ash woodlands on ungrazed-grazed and thinned-unthinned post-treatments with means of the first six years compared to the 25th year (stems/ha ± standard error) north of Belfield ND. Means adjusted by covariance

Category	Post-treatment year	Ungrazed	Grazed	Thinned	Unthinned
Green Ash	1-6[1]	2224 ± 164	2765 ± 344	3487 ± 214	1502 ± 312*
	25[2]	807 ± 648	3220 ± 1660	1600 ± 571	2427 ± 1687
American Elm	1-6	1567 ± 266	5127 ± 623*	5435 ± 565	1257 ± 458*
	25	460 ± 269	62 ± 62	198 ± 222	324 ± 224
Chokecherry	1-6	1582 ± 376	2199 ± 524*	1560 ± 367	2222 ± 502*
	25	5780 ± 6411	10396 ± 5194	14754 ± 3677	1421 ± 7359
Serviceberry	1-6	2609 ± 379	1620 ± 195*	1880 ± 327	2348 ± 212
	25	5268 ± 1955	4799 ± 2182	5127 ± 2092	4941 ± 2066
Woods Rose	1-6	13497 ± 936	12938 ± 689	12702 ± 564	13733 ± 740
	25	5178 ± 1969	5785 ± 2281	7771 ± 2322	3192 ± 1428
Spiny Currant	1-6	3311 ± 316	2862 ± 315	2842 ± 227	3295 ± 331*
	25	273 ± 444	2808 ± 2033	2542 ± 1976	1560 ± 407
Snowberry	1-6	98802 ± 6995	96611 ± 6977	103941 ± 8352	91472 ± 6170*
	25	300351 ± 44515	367092 ± 46872	393076 ± 24419	274368 ± 39106*

[1] mean of 6 years post treatment (1976-1981), n = 6 years.

[2] mean of 25th year (2001) post treatment. n = 6 sites

* Significant at $p < 0.10$.

Herbaceous Standing Crop

Standing crop estimates were significantly greater ($p = 0.03$) on the ungrazed than on the grazed treatment over all post-treatment years with a 36% difference in total herbage (Table 4). During the fifth year post-treatment, grasses, forbs and total standing crop of all vegetation were significantly different between treatments. Average total standing crop for all post-treatment years was 1596 kg•ha^{-1} (ungrazed) and 1173 kg•ha^{-1} (grazed). Grasses yielded 1353 kg•ha^{-1} on the ungrazed and 1016 kg•ha^{-1} on the grazed treatments. Standing crop of forbs was low with 243kg•ha^{-1} and 158 kg•ha^{-1} on ungrazed and grazed treatments, respectively. Precipitation for 2001 (25 year post treatment) was greater than the long-term mean while post treatment years 4-6 (1979-1981) were less than the long-term average.

Removal of 40% decadent overstory trees resulted in a significant increased total standing crop of understory vegetation ($p = 0.07$) when considering all post-treatment years with a 16% increase compared to the uncut treatment (Table 4). There were no treatment differences within individual post-years but standing crop was variable between and among years. All other years (years 4,6, and 25) were variable with no treatment differences. Average total standing crop for all post-treatment years was 1487 kg•ha^{-1} and 1282 kg•ha^{-1} on thinned and unthinned treatments, respectively. Grasses yielded 1291 kg•ha^{-1} on thinned and 1078 kg•ha^{-1} on unthinned treatments. Average yield of forbs was 196 kg•ha^{-1} and 205 kg•ha^{-1} for all post-treatment years on thinned and unthinned treatments, correspondingly.

Table 4. Standing crop within green ash woodlands during late August-early September on ungrazed-grazed and thinned-treatments after 4 to 25 years (kg/ha ± standard error) north of Belfield ND.

Category	Post-treatment year	Ungrazed[1]	Grazed	Thinned	Unthinned
Grass	4-1979	1352 ± 406	818 ± 185	1266 ± 341	904 ± 170
	5-1980	1058 ± 113	518 ± 93*	917 ± 152	659 ± 144
	6-1981	901 ± 110	770 ± 147	904 ± 97	767 ± 155
	25-2001	2101 ± 538	1956 ± 383	2077 ± 471	1980 ± 464
Forb	4-1979	135 ± 58	86 ± 29	112 ± 54	109 ± 38
	5-1980	95 ± 22	42 ± 7*	72 ± 19	65 ± 22
	6-1981	121 ± 33	90 ± 25	118 ± 24	92 ± 34
	25-2001	621 ± 138	413 ± 50	482 ± 119	552 ± 106
Total	4-1979	1487 ± 387	904 ± 199	1378 ± 423	1013 ± 178
	5-1980	1153 ± 100	560 ± 99*	989 ± 156	724 ± 154
	6-1981	1022 ± 86	860 ± 156	1022 ± 103	859 ± 145
	25-2001	2723 ± 508	2369 ± 367	2559 ± 403	2533 ± 493

[1] n = 6 sites/treatment.
* Significant at $p < 0.10$.

Discussion

Green ash woodlands on the Northern Great Plains have existed for many years and have been documented along the Missouri River and its tributaries since the 1870's and 1880's (Rumble et al. 1998, Severson and Sieg 2006). These woodlands were common prior to early European settlement but have been heavily modified by cultivation, urbanization and livestock grazing. Many of the woodlands have been altered by variations of livestock management with many woodlands becoming decadent with little regeneration while others have been replaced by grasses and forbs (Severson and Boldt 1978, Boldt et al. 1978, Uresk and Boldt 1986, Lesica and Marlow 2013). Regeneration of native green ash woodlands to a desired successional seral stage as defined by resource managers may be a long-term process. Recruitment of green ash seedlings by seed from mature trees in wooded draw systems is not common. Our observations show that seeds sprout, but competition by grass and grazing eliminates most seedlings. Lesica (2009) reported similar results with seed sprouting. A few ash seedlings do survive within the cover of snowberry (Uresk, personal observations) or in and around adjacent felled trees where grazing and grass competition are reduced.

Cutting and removal of decadent overstory trees resulted in sprouting from the stumps. Protection from grazing was beneficial for tree sprouts at the 5 year post-treatment and after exclusion from grazing for 25 years, the number of stumps with sprouts remained constant. Under a three pasture deferred grazing system, 36% of the stumps had no sprouts. After 25 years, heights of tallest sprout stems on ungrazed treatments were 79 dm, approximately twice as tall as on the grazed treatment. Lesica (2009) reported stem heights from stumps after less than 20 years at 70 dm in eastern Montana. Protection from grazing of sprouts from cut stumps for 5 years is recommended until the terminal stems reach a height of 16 dm. Green ash stems > 16 dm will become mature trees. Protection from grazing for 5 years will meet this requirement with green ash and other trees.

For example, Smith et al. (1972) reported average heights of stems 15 dm was required to minimize damage to aspen terminals from being browsed.

Survival and growth of planted shrubs and trees were variable among species. Rocky Mountain Juniper, bur oak and chokecherry had very good survival from plantings after 25 years with no grazing, but much lower with livestock grazing. Protection of shrub and tree plantings from grazing enhanced survival. However, reduction in livestock stocking rates or grazing pastures early during the growing season before cattle utilize shrubs, tree sprouts and seedlings in the woodlands would be beneficial (Roath and Krueger 1982, Holechek et al.1982, Uresk and Paintner 1985, Lesica and Marlow 2013). Plantings may be a cost prohibitive method to replace decadent stands on the northern Great Plains. However survival could be enhanced by excluding livestock grazing.

Regeneration of shrubs in green ash woodlands is a slow process, but some shrubs responded positively with cultural treatments during the first six years of post-treatment (Uresk and Boldt 1986). Indications are that most shrub responses to treatment did not change after six years. Shrubs and trees that increased stem density during six year post-treatment period with grazing in a three pasture deferred grazing system were American elm, chokecherry, and serviceberry, while other shrubs were static at the end of six years. The unthinned cultural treatment was beneficial, averaged over the six year period for chokecherry and spiny current while snowberry decreased. Thinning overstory decadent trees increased stem density of green ash and American elm. However, at 25 years post-treatment, snowberry stem density decreased in the unthinned treatment. The decrease can be attributed to the increased tree density and canopy cover providing shade and competition with increased density of shrubs. Similar results were reported by Lesica (2009) and Lesica and Marlow (2013) in eastern Montana.

American elm's decrease could be somewhat influenced by infections of Dutch elm disease or Dothiorella wilt during the past 20 years of the study as indicated with additional dead mature stems and many dead sprouts (Stack and Laut 1986, Krupinsky and James 1986). However we did not investigate disease during this study, but a greater number of American elm trees had died compared to green ash between 1981 and 2001.

The emerald ash borer (*Agrilus planipennis*), a native of China, was possibly introduced into eastern United States through wood packing material for shipping items around 1990's and has spread to over 20 states and two Canadian provinces (Liang and Fei 2014). However, it has invaded areas with a milder climate and a longer growing season of 150 days with annual precipitation of 51cm-102cm (20-40 inches) (Lesica and Marlow 2013). Many areas in the Dakotas, and Wyoming have shorter growing seasons and less precipitation. Our study area had a growing season of 112 days and 41cm (16 inches) of precipitation with harsh winters (Climod 2 2016). Climate suitability prediction for models by Liang and Fei (2014) for the emerald ash borer, indicate green ash woodlands commonly confined to draws on the northern Great Plains prairie region, generally indicate a range from unsuitable to low suitability habitat for the ash borer. The emerald ash borer is not expected to tolerate these harsher and drier conditions.

Many green ash stands are not regenerating because of livestock and wildlife browsing sprouts and seedlings. Grazing promotes sod forming grasses that out-compete young seedlings (Uresk and Boldt 1986, Lesica and Marlow 2013). Excluding livestock by fencing ash woodlands in need of regeneration is expensive and alternative grazing systems should be considered. Green ash woodlands in mid to late seral stages were in pastures considered in excellent condition. The uplands were not heavily used by cattle resulting in limited use within the green ash draws. A successful method for regeneration

of aspen stands is to reduce livestock and wildlife grazing by hinging (cutting tree stems) (Kota and Bartos 2010). Hinging consists of cutting tree stems approximately 1m or lower above ground but maintaining stem connection to the stump. Although not tested in green ash woodlands, hinging decadent ash trees may be feasible to limit livestock grazing in these woodlands instead of fencing to promote regeneration of ash seedlings, sprouts and increased shrubs densities. Other regeneration methods are presented by Lesica and Marlow (2013).

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An Ecological Model to Classify and Monitor Mountain Plover Nesting Habitat on Grasslands in Colorado

Daniel W. Uresk, USDA Forest Service, Rapid City SD 57701

Abstract

A multivariate statistical model based on vegetation and soil surface characteristics was developed to classify and monitor mountain plover (*Charadrius montanus*) habitat groupings and nest selection. Data were collected on the shortgrass prairie, Pawnee National Grassland, Colorado. Vegetation and soil surface characteristics were sampled from late April to early June of 1999 and 2000 during the nesting season. Samples were collected on random sites in 43 sections and at 54 nest sites within adjacent townships. Random data were clustered into three habitat groups consisting of high, mid and low nesting habitat. Key variables in the model for classifying and monitoring nest habitat were percent bare ground, percent canopy cover for blue grama (*Bouteloua gracilis*) and buffalograss (*Bouteloua dactyloides*). The three nest habitat groupings were quantitatively identified with an estimated 97 percent accuracy. The model classified the 54 mountain plover nest sites as either high, mid or low nesting habitat. High mountain plover nest preference (39 nests) for bare ground was 46 percent, with blue grammar 27 percent and buffalograss at 2 percent (n = 39 nest sites). Mid classified nests (12) selected 23 percent bare ground, 60 percent blue grama and 1 percent buffalograss. Three nests were classified as low nesting habitat, which exhibited 25 percent bare ground, 41 percent buffalograss and 17 percent blue grama. Mountain plovers selected nest sites that had short plant structure, a mean visual obstruction reading (VOR) of 0.25 cm at nesting and ranged from 0 to 1.6 cm. Nest selection was similar for VOR among the three groups ($P > 0.10$). Plant structure (VOR) from 499 random sites was grouped into three categories; tall, intermediate and short and ranged from 0.6 to 11.4 cm. Short VOR plant structure of 2.2 cm or less (<1-inch) is potential nesting habitat and may be achieved by fall or winter grazing within high plover nesting habitat. This multivariate model along with visual obstruction groupings for classifying and monitoring mountain plover habitat on the shortgrass prairie are simple to use, reliable, repeatable and cost effective to meet management objectives and monitoring plans.

Key words: Habitat classification, monitoring, nest selection, plant structure, visual obstruction reading.

Introduction

The mountain plover (*Charadrius montanus*) generally nests in the shortgrass prairies on level sites with sparse, short vegetation and patches of bare ground associated with heavy herbivore grazing (Graul and Webster 1976, Olson and Edge 1985, Dreitz et al. 2005, Plumb et al 2005, Augustine and Derner 2012, Javersak et al. 2012). Bradbury (1918) described a mountain plover nesting area 20 miles east of Denver, Colorado (CO) as cattle range with buffalo and grama grasses, some prickly pear and few shrubs or weeds. In Weld County, CO, Graul (1975) reported mountain plovers were nesting in short grass habitat primarily consisting of blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*) with dispersed clumps of plains prickly pear (*Opuntia polyacantha*). In 1999, the mountain plover was originally proposed as threatened or endangered according to the Endangered Species Act of 1973 (Federal Register 2011) and withdrawn in 2003. However, in 2010,

the mountain plover was again proposed as a threatened species but was withdrawn May 12, 2011. The mountain plover was not determined to be threatened or endangered throughout all or a substantial portion of its range. Nevertheless, the mountain plover should receive continued investigation and monitoring to maintain or enhance existing populations. Restoring or maintaining areas for mountain plover nesting habitat through livestock grazing can be achieved through plant succession and defining seral stages that meet the desired nesting requirements on the short grass prairie in Colorado (Ryder 1980, Uresk 1990, Knopf and Miller 1994, Knopf 2008, Augustine and Derner 2012). There is little information focusing specifically on the use of heavy livestock grazing to meet the nesting habitat requirements through plant succession and defining the optimal nest habitat groupings for selection of nest sites. The purpose of this study was to develop a habitat model for habitat classification and monitoring based on plant succession within the short grass prairie to determine optimum nesting habitat for mountain plovers.

Study Area

This study was located near Briggsdale and Keota in Weld County, CO, within the western unit of the Pawnee National Grassland. The grassland includes 78,162 ha of publicly owned tracts of land intermixed with private farms and ranches. Average precipitation from 1981-2010 at Briggsdale was 34 cm (13.4 inches) (CLIMOD 2017). Average length of the growing season ranges from 151 to 178 days. Mean monthly temperatures range from a low in December of - 4^0C to 22^0C in July. The area is classified as a shortgrass steppe (US Department of Agriculture Natural Resources Conservation Service [USDA NRCS] 2017) with blue grama, buffalograss, plains prickly pear, western wheatgrass (*Pascopyrum smithii*) and sun sedge (*Carex inops*) as the primary plant species. Soils are an Ascalon-sandy loam, a deep well-drained Ustollic Haplargid (Crabb 1982, USDA NRCS 2017).

Methods

Mountain plovers were most frequently found on loamy plains range sites with less than 2 percent slope and a southern to southwestern aspect in the study area. Searching for individual plovers began at sunrise and continued through sunset during the nesting period. Searching for nests and all other data collections was completed from late April to early June during 1999 and 2000. Mountain plover nesting was documented from May 14 through June 8 for the two year study. Once a plover was located, it was observed until it settled on the nest. Later, the nest was located and visual obstruction readings (VOR) with the modified Robel pole and cover estimates were completed in a very short time frame, less than 10 minutes (Daubenmire 1959, Uresk and Benzon 2007, Uresk and Juntti 2008).

The experimental design consisted of sampling within a 2 m diameter area around nest sites located on random transects within 1 square mile sections (259 ha). Major plant species, total grasses, total forbs, total cover, bare ground and ground litter were sampled following methods for canopy cover described by Daubenmire (1959). A quadrat (20 cm x 50 cm) was placed in four cardinal directions (North, South, East, West) within the 2 m diameter area for data collections. One quadrat was placed over the nest area for a total of five quadrats per nest area. This experimental design was applied at each stratified random site on the grasslands. All canopy data estimated from the five quadrats were summarized into one mean per site. Therefore, all nests and random sites were unique for analyses.

The modified Robel pole (2.54 cm) had alternating 1.27 cm white and gray bands. These bands were numbered beginning with 0 (white band) at the bottom and the pole was placed at the edge of the nest, but at stratified random points in the center of the 2 m diameter area. The lowest visible band was read 4 m from the pole and at a 1 m height following procedures described by Uresk and Benzon (2007) and Uresk and

Juntti (2008). Four VOR measurements were collected at each pole station in each cardinal direction. The 4 VOR measurements were summarized into one mean for analyses.

Random sampling as well at mountain plover nest sites was conducted in three areas on the Pawnee grasslands for the Robel pole, VOR and canopy cover estimates of vegetation and bare ground. Three areas were located, two at Briggsdale: (1) Northwest, Townships 10 and 11 north, Range 64; (2) West,Townships 8 and 9 north, Range 62 and 63. A third area was located south of Keota: (3) Township 8 north, Range 59 and 60. A total of 43 sections were surveyed in these three areas during 1999, but only 28 of the same sections (Area 1 and 3) were sampled for both canopy cover and Robel pole measurements (VOR) in 2000. An additional 15 sections (area 2) were sampled for Robel pole measurements only. Limited sampling within sections was constrained by fences and rough terrain.

Random transects were selected for each land section prior to data collection and new random sites were selected during the second year of sampling. An all-terrain vehicle (ATV) was driven within each section in a line coordinated with Global Positioning System (GPS) units. Sites were sampled on the random 1.6 km (1 mile) transect beginning at 0 and 0.3 km (0.2 mile) increments thereafter within each section. Six sampling sites for canopy cover and visual obstruction readings were collected per transect for 416 sites on the 43 sections. An additional 83 sites were collected for visual obstruction measurements in area 2 for a total of 499 sites during the two-year period.

All random data for cover variables and visual obstruction readings were combined for both years (1999, 2000) for analyses. Preliminary examination of 21 variables from data analysis for cover data removed minor plant species, annuals, total cover, graminoids and forbs resulting in 10 variables, including bare ground, following procedures described by Uresk (1990) and Uresk and Mergen (2014). These 10 variables were further reduced by principal component analysis to five variables. A non-hierarchical cluster analysis (ISODATA) defined three groupings based on five variables to evaluate potential mountain plover nesting habitat based on plant successional seral stages (Ball and Hall 1967, del Morel 1975). Cover variables for 416 cover sites and 499 VOR sites were used to develop potential nest resource grouping and guideline based minimum variances within a cluster. Clusters are unsupervised and are defined by the ISODATA algorithm. Stepwise discriminant analysis was used to estimate compactness of the cluster and identified key variables, estimated differences between and among clusters, to develop Fisher classification coefficients for model development (Uresk 1990, SPSS 2003). Discriminant analyses identified three key variables for classifying plover nest habitats and for monitoring based on plant succession and surface soil characteristics. Cluster groupings based on vegetation successional status were defined for plover nest habitats as high, mid and low. Misclassification error rates were estimated with a cross validation using a jackknife or "leave one site out" procedure (SPSS 2003, Uresk and Mergen 2014).

The developed Fisher coefficients from discriminate analyses based on the three clusters and key variables from random sites classified the 54 nest sites into three nest groupings. The three nest groupings characterized by major variables provide information on the selection of nest sites. Robel pole VOR among nest grouping were evaluated by analysis of variance (SPSS 2003).

Results

Random Sites

A total of 21 variables were sampled on 416 sites. This included graminoids, forbs, shrubs, total cover, litter and bare ground. The 21 variables were reduced to five variables: blue grama, buffalograss, plains pricklypear, sun sedge and bare ground.

These five variables were then evaluated by a non-hierarchical cluster analyses (ISODATA) resulting in three groupings (high, mid and low) defined as nesting habitats. Stepwise discriminant analysis of the groupings resulted in three variables; bare ground, blue grama and buffalograss, that evaluated compactness (P<0.05) of clusters and development of Fisher model coefficients (Table 1).

Fisher classification discriminant coefficients by size show the importance for each of the three variables (bare ground, blue grama and buffalograss). These coefficients provide the information for classifying plover nesting habitat on the grasslands and monitoring mountain plover habitat (Table 1). Cross validation (jackknife procedure) results for the three nesting habitats showed a misclassification rate of 3 percent. Overall accuracy for nest assignment was 97 percent. When key canopy cover variables (%) are collected from a site, multiplied by Fisher coefficients and summed accounting for the constants, the most positive score assigns the classification of nesting habitat based on the three defined variables. An example of calculating scores from Fisher coefficients and assigning it to the nest habitat groupings is presented in Uresk and Mergen (2014).

Table 1. Fisher's discriminant function coefficients and constants used in model. Classification and monitoring of three mountain plover nesting habitats (high, mid, low) (n = 416 random sites) on the Pawnee National Grassland, 1999-2000. See Uresk and Mergen (2014) Table 3 for an example of assigning nesting habitat from new data collected on the grasslands.

Variable	High	Mid	Low
Bare ground	0.330	0.268	0.357
Blue grama	0.247	0.455	0.263
Buffalograss	0.246	0.233	1.471
Constant	-10.088	-17.884	-45.416

The estimated number of random transects required per section (six sites per transect) to achieve a precision of 20 percent of the mean with 80 percent confidence is three.

The dynamics of these three key variables for plover nesting habitat based on plant succession and bare ground for 416 sites throughout the three nesting habitats are illustrated in Figure 1, Table 2. Key variables for high plover nesting habitat on the grasslands were dominated by bare ground (33%), followed by blue grama (25%) and buffalograss (3%). The mid nesting habitat was greatest for blue grama with 64 percent canopy cover followed by bare ground (5 %) and buffalograss (2 %). Low nesting habitat was dominated by buffalograss with 53 percent canopy cover followed by blue grama (16 %) and bare ground (19 %).

High Nesting Habitat

Canopy cover within the high nesting stage is dominated by blue grama (25%) and Fendler threeawn (*Aristida purpurea*) (7%), followed by western wheatgrass (5%) and buffalograss (3 %) (Table 2). Total canopy cover and graminoid cover was 51 percent and 45 percent, respectively. Forb and shrub cover was five and 4 percent, respectively. Bare ground represented 33 percent and was the greatest of the three nest habitat stages.

Mid Nesting Habitat

Blue grama exhibited 64 percent cover, the greatest of all three stages (Table 2). All other species were minor with less than 4 percent cover. Total plant cover and graminoid cover were 75 and 72 percent, correspondingly. Bare ground was low with 15 percent cover and ground litter with 19 percent cover.

Low Nesting Habitat

Buffalograss was dominant with 53 percent cover, while the other two stages were less than 3 percent (Table 2). Cover for blue grama, a co-dominant, was 16 percent. Low cover values were exhibited by all other grass and sedge species, ranging from 2 to 4 percent.

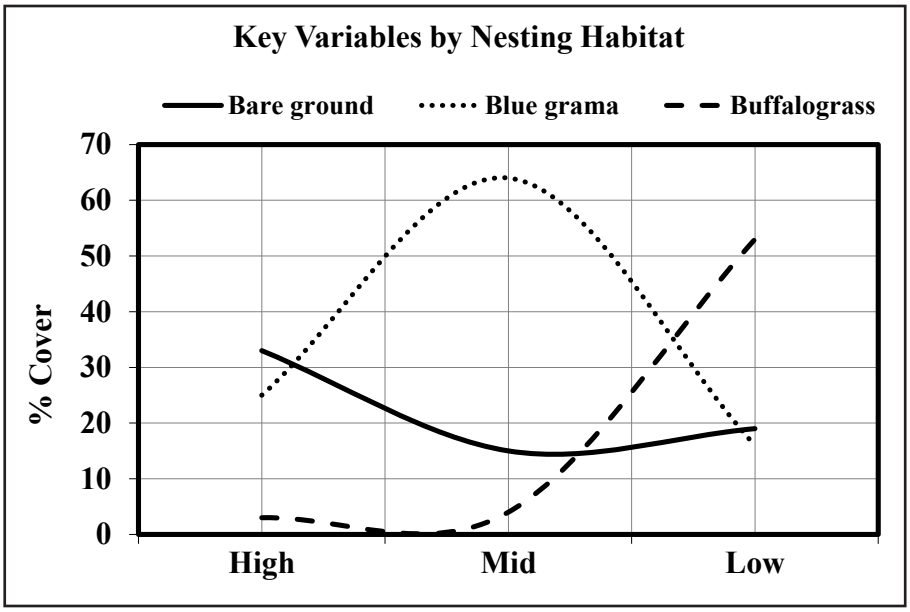

Figure 1. Key variables displayed throughout the three grouping for nest habitat in a blue grama, buffalograss, and western wheatgrass ecological type from late April to early June. Grouping of mountain plover nest habitat based on data from random sites, Pawnee National Grassland, Colorado.

Visual Obstruction Readings

Visual obstruction readings for 499 random sites ranged from 0 to 15.2 cm with an overall mean of 1.7 cm. Means of three VOR categories ranged from 0.6 to 11.4 cm (Table 3). Random areas on the grasslands with a mean VOR of 0.6 cm for the short category, ranging from 0 to 2.2 cm, is considered the most probable category for plover nesting habitat.

Nest Site Selection

Mountain plover nests assigned to the three seral nesting categories by the developed Fisher coefficients show that they are highly selective for nests in patches of high bare ground (Table 4). Thirty-nine out of 54 nests selected by plovers were characterized by 46 percent bare ground, 27 percent blue grama cover and 2 percent cover for buffalograss. Twelve plover nests were selected in sites with 23 percent bare ground, 60 percent blue grama and 1 percent cover for buffalograss. Only three nests were selected in areas dominated by buffalograss (41%), followed by blue grama (17 %) and bare ground (25 %). The optimal nest selection sites for mountain plovers on grassland habitats are located within the high nesting habitat with greater amounts of bare ground in areas dominated with blue grama. Visual obstruction readings for the 54 nests ranged from 0 to 1.6 cm and averaged 0.25 cm among the three nest categories. There were no VOR differences among the three nest categories ($P > 0.10$). Additional canopy cover (%) for all 13 major variables by nest habitat selection is presented in Table 5.

Discussion

Monitoring the dynamics of bare ground, blue grama and buffalograss on the grasslands can be used to describe successional changes between and among seral stages defined as plover nesting habitat. Disturbances such as livestock grazing, fire and climatic changes can shift the three variable association or abundance with respect to the quality of the nesting habitat (low, medium or high). The multivariate model provides natural resource managers a tool for monitoring the status of the vegetation and bare ground on the

Table 2. Mean canopy cover (%) and standard errors (parentheses) of common plant species and other variables by plover nesting habitat (high, medium, low) on the grasslands from late April to early June (n = 416 random sites) on the Pawnee National Grassland, 1999-2000.

Species or variable	High [1]	Mid	Low
Western wheatgrass *Pascopyrum smithii*	5.1(0.7)	2.6(0.3)	1.5(0.6)
Blue grama *Bouteloua gracilis*	25.1(1.0)	64.3(0.9)	15.6(2.0)
Buffalograss *Bouteloua dactyloides*	3.1(0.5)	1.5(0.3)	52.9(3.0)
Fendler threeawn *Aristida purpurea*	6.6(1.0)	1.9(0.4)	1.5(0.6)
Sun sedge *Carex inops*	3.3(0.6)	4.1(0.4)	3.7(1.7)
Plains pricklypear *Opuntia polyacantha*	3.8(0.5)	3.8(0.4)	3.6(1.2)
Sixweeks fescue *Vulpia octoflora*	2.4(0.5)	2.4(0.5)	1.7(0.6)
Total plant cover	50.5(1.3)	75.0(0.8)	75.2(2.3)
Graminoid cover [2]	45.3(1.3)	71.8(0.9)	73.2(2.4)
Forb cover [2]	4.6(0.5)	3.1(0.3)	3.7(0.8)
Shrub cover	3.9(0.5	3.8(0.5)	4.9(1.8)
Litter cover [3]	11.8(0.9)	19.0(1.2)	8.2(1.8)
Bare ground	33.4(1.3)	14.7(0.5)	18.8(2.3)

[1] Sample size: High =153; Medium =238; Low =25
[2] Two dimension cover and not the sum of the individual plant species.
[3] Ground litter.

Table 3. Robel pole VOR for vegetation structure on random sites for the short grass prairie from late April to early June. Mean and range (cm) on the Pawnee National Grassland, 1999-2000.

VOR	Sites [1]	Mean (SE) [2]	Range
Tall	15	11.4(0.6)	8.3 – 15.2
Intermediate	106	4.2(0.1)	2.5 – 7.6
Short	378	0.6(0.1)	0.0 – 2.2

[1] = number of random sites
[2] = Standard error

Pawnee grasslands within the blue grama, buffalograss, plains prickly pear and western wheatgrass habitat type in an attempt to manage for desired plover nesting habitat. In this study, short structure vegetation (VOR) that ranged from 0 to 2.2 cm had the greatest potential for plover nesting habitat on the grasslands. Both monitoring tools define nesting habitat with percent cover of bare ground, blue grama, buffalograss and VOR for vegetation structure.

Mountain plover nests assigned to the three nesting categories are extremely selective for nests located in the high nesting habitat type (72%) with 46 percent bare ground, 27 percent blue grama and little

Table 4. Mean canopy cover (%) and standard error (parentheses) of key plant species for assigned mountain plover nest sites (n= 54). Classified from Fisher coefficients developed from random sites and assigned to nest habitat on the Pawnee National Grassland, 1999-2000.

		MEAN CANOPY COVER (%)		
Nest sites	**Nests [1]**	**Bare Ground**	**Blue Grama**	**Buffalograss**
High	39	46(2.6)	27(2.4)	2(0.7)
Mid	12	23(2.1)	60(2.8)	1(1.0)
Low	3	25(10.9)	17(8.9)	41(7.4)

[1]= number of nests

Table 5 Average canopy cover (%) and standard errors (parentheses) of plover nest sites assigned by Fisher coefficients from random sites by nest habitat from late April to early June (n = 54 nests) on the Pawnee National Grassland, 1999-2000.

Species or variable	**High [1]**	**Medium**	**Low**
Western wheatgrass *Pascopyrum smithii*	0.9(0.4)	0.3(0.2)	1.5(0.9)
Blue grama *Bouteloua gracilis*	26.8(2.4)	58.9(2.8)	17.3(8.9)
Buffalograss *Bouteloua dactyloides*	2.2(0.7)	1.3(1.0)	40.5(7.4)
Fendler threeawn *Aristida purpurea*	1.9(0.6)	0.9(0.6)	0.0
Sun sedge *Carex inops*	0.8(0.3)	3.3(1.2)	4.7(2.1)
Plains pricklypear *Opuntia polyacantha*	1.4(0.5)	1.5(0.5)	0.0
Sixweeks fescue *Vulpia octoflora*	0.5(0.3)	0.1(0.1)	0.0
Total plant cover	40.0(1.9)	62.9(2.8)	59.2(14.7)
Graminoid cover [2]	35.4(1.9)	61.2(1.9)	56.2(15.7)
Forb cover [2]	3.0(0.7)	1.2(0.6)	4.7(3.9)
Shrub cover	0.8(0.3)	0.6(0.3)	0.0
Litter cover	9.0(1.1)	23.4(4.9)	9.0(4.3)
Bare ground	45.8(2.6)	23.4(2.1)	25.3(10.9)

[1] Sample size by nest habitat: High =39, Medium = 12, Low = 3.

[2] Two dimension cover and not the sum of the individual plant species.

or no buffalograss. Only three nests (6%) were in low nesting habitat dominated by buffalograss (41%) and bare ground (25%).

In Colorado, Javersak et al. (2012) reported nesting sites that were primarily located in areas with an average of 24 percent bare ground and Knopf and Miller (1994) reported nests with 32 percent bare ground. In Montana, Olson and Edge (1985) reported 27 % bare ground (erosion

pavement) for nest sites. Parrish et al. (1993) and Plumb et al. (2005) reported plover nest selection at areas of 72% and 47% bare ground, correspondingly, in Wyoming.

Visual Obstruction Readings at 54 nest sites were similar for all three nest groupings and averaged 0.24 cm in this study. Javersak et al. (2012) reported an average VOR of 0.6 cm for 16 plover nest sites on the Pawnee grasslands in Colorado. Parrish et al. (1993) in Wyoming reported VOR of 0.13 cm. The reported Visual Obstruction Readings define a range nest sites selected and preferred by mountain plovers on the grasslands.

Livestock grazing on the grasslands can significantly influence and alter vegetation composition and structure for wildlife (Severson 1990, Severson and Urness 1994, Derner et al. 2009). To create or maintain optimal mountain plover habitat, grazing intensity should be heavy within grassland areas dominated by blue grama with sparse buffalograss. Visual Obstruction Readings, ranging from 0.6 cm to 2.2 cm may be achieved by grazing livestock late fall and/or winter months. Livestock numbers and length of time of grazing on the grasslands is ancillary. The objective is to achieve the recommended visual obstruction reading of 2.2 cm (approximately <1-inch) or less, even if it takes a month grazing with few herbivores to several days with a greater number of herbivores. Establishing artificial treatment (burning, mowing) patches (16 ha or 40 acres) is expensive and difficult to manage throughout public grasslands. Grazing these areas will provide bare ground and short structure within areas defined as high nesting habitat that is preferred by mountain plovers. Continued heavy grazing over time of these areas will move the plant successional stage to a sod forming dominant buffalograss with sub dominant blue grama stage (USDA-NRCS 2017, Augustine and Derner 2012) and will require a rotation grazing system to create mountain plover nesting habitat.

Monitoring for VOR and three key variables (bare ground, blue grama, buffalograss) on the short grass prairie will provide information to help determine desired conditions to manage for preferred plover nesting habitat. The developed model for classification and monitoring with three key variables and with VOR are two tools that are simple, cost effective and repeatable. These two tools provide protocols and guidelines for managers to meet, sustain, or improve mountain plover nesting requirements.

Conclusion

Mountain plovers nest in the shortgrass prairie in select areas with a high percentage of bare ground, low canopy cover and low VOR near nests. Specifically, conditions for ideal nesting habitat for mountain plovers include at least 46 percent bare ground, 27 percent blue grama cover and little to no buffalograss. Additionally, vegetation structure (VOR) grazed to approximately 1-inch or less, ranging from 0.6 to 2.2 cm defines potential plover nest site selection on the grasslands when grazed late fall and /or winter months. These guidelines should be beneficial and effective in providing desired nesting conditions to achieve or sustain the habitat for mountain plover conservation. Agricultural land under cultivation, provided some nesting habit for mountain plovers, but mortality was high. Mountain plovers primarily inhabitant the grasslands for nesting and chick rearing.

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Montana Chapter of The Wildlife Society

55nd Annual Conference, 2017

Habitat: The Science, Art and Politics of Conserving It

March 6-10, 2017

Helena, Montana

Vanna Boccadori, President 2017-18
Montana Chapter of The Wildlife Society

Held Jointly with the Northwest Section of The Wildlife Society

Introduction

This year's theme was Habitat: The Science, Art, and Politics of Conserving It. The idea for this came about when I thought about all the factors that have to be navigated to develop and implement a successful habitat project. From the science perspective, you need to understand the habitat that you're working in, its ecological state, function and disturbance ecology and apply appropriate science. Then there's the matter of scale. To be more effective, many projects are applied at the "landscape-level", which means you're often working across landownerships and therefore have to navigate the different side boards and mandates that each agency must work within. While agency folks trip their way through the bureaucratic hurdles to get their projects done, private landowners maintain 70% of the land base in Montana, including valuable habitat for wildlife. Habitat can be enhanced or reduced depending on the land use practices. Land trust organizations, non-governmental organizations, private landowners, and state and federal agencies must work cooperatively to conserve and enhance wildlife and fish habitat. And all of this can become that much more complicated depending on the political winds that are blowing at the time.

This year's plenary session and banquet presentation were designed to explore some of these influences affecting habitat conservation and management. At the plenary panel we heard from Jeff Laszlo, a private landowner engaged in large-scale habitat work on his ranch in the Madison Valley; Jeff Herbert, a retired FWP biologist speaking to the active influence that sportsmen and women have had on habitat conservation in Montana; Bok Sowell, an Montana State University professor of range ecology challenging our interpretation of scientific studies; Martin Nie, a University of Montana professor specializing in natural resource policy on western public lands and the need to improve forest plans rather than dispose of federal lands; and Jennifer Fielder, a state senator who supports the transfer of federal lands to the state so they can be better managed.

Greg Neudecker was our banquet speaker. He is the state coordinator for the Montana Partners for the Fish and Wildlife Program with the USFWS. He's worked with well over 500 landowners on projects ranging from conservation easements, fee acquisition, instream restoration, wetland restoration, grazing management and grizzly bear conflict abatement. His presentation addressed how science, art and politics shaped the successful collaborative habitat conservation program that has come to be known as the Blackfoot Challenge in the Blackfoot Valley of western MT. Over 300 wildlife professionals attended this year's conference.

Plenary Session Abstracts

Alphabetical By Presenter's Name

Transfer of Federal Lands to the State

Jennifer Fielder, Montana State Senate - District 7, Thompson Falls

The federal government owns over half of all land in western America. This is not only unfair, it is not working. Some of this land can and should be transferred to the states so it can be tended with greater care and accountability. Restoring the balance and strengthening the local voice in public land management will lead to better outcomes in environmental quality, economic productivity, recreational opportunity and social harmony. A variety of historic, legal, economic, political and environmental factors support the viability of transferring certain federally controlled public lands to the States.

Sportsmen's Engagement in Conservation in Montana

Jeff Herbert, Retired MT FWP wildlife biologist, Helena

Montana represents a very successful and effective model of conservation relative to its fish, wildlife and habitat resources. It is nationally recognized as such. Foundational to this model of conservation is the public trust doctrine and the premise that these resources are to be managed in perpetuity for the benefit of all. It includes an underpinning of rigorous science to guide management decisions and actions and a democratic opportunity for the citizens of this state and our guests to participate in a variety of regulated recreational opportunities. Montana provides a blend of public and private lands including the presence of two significant national parks, several major wilderness areas and working landscapes that contribute to the physical and economic well being of this state. Most importantly, the people of Montana have been committed to the support of this model, uniquely so when it comes to local and statewide engagement. Montana hunters, anglers and conservationists have a history of participation in decisions relative to population management, habitat conservation and access issues.

Transforming Land, Transforming People

Jeff Laszlo, Granger Ranches, Madison Valley, MT

Norman Mclean wrote, "Eventually all things merge into one, and a river runs through it."Restoration is about reconnecting water to land, living things to their former habitats and people to each other. The O'Dell Creek Headwaters Restoration project is a collaborative multi partner effort to restore wetlands and degraded stream channels from O'Dell's headwaters to its confluence with the Madison River 12 miles downstream. The project began in 2005 on The Granger Ranches with funding provided by PPL Montana (now Northwestern Energy). The results were immediately apparent and the work accomplished in the Phase 1 project quickly gained support from Montana Fish Wildlife and Parks, Ducks Unlimited, Trout Unlimited and the US Fish and Wildlife Service. The potential for this project as well as its public benefits have led to an extensive and growing public private partnership that continues to evolve. Nonprofits such as The Trust for Public Land, The Montana Land Reliance and The Madison River Foundation along with neighboring ranches and The Patagonia Company have also become highly engaged partners. Regular visits from

student groups, agency personnel, the ranching community and wounded veterans fishing organizations have been an integral aspect of reconnecting people to the land and have provided important educational benefits from both the project's outcomes and its partnerships. A decade since the project's inception all the major drainage canals have been closed and the restored wetlands now host over 200 plant species including 6 listed by the state of Montana as "Species of Concern". Monitoring by the University of Montana's Avian Science Center has documented an increase from 10 bird species to approximately 130. Water temperatures in the restored stream channels have been substantially reduced and stabilized. Efforts to re-introduce threatened Trumpeter Swans and Arctic Grayling are ongoing. One thousand Greater Sandhill Cranes have been observed staging along O'Dell prior to fall migration. Simultaneously, the Granger Ranches has grown ints livestock operations, demonstrating that healthy and diverse habitat can coexist along with sustainable ranching. The O'Dell Project has succeeded beyond anyone's expectations.

Transferring Federal Lands to States: Unanswered Questions and Implications for Wildlife

Martin Nie, Director, Bolle Center for People and Forests; Professor, Natural Resources Policy; W.A. Franke College of Forestry and Conservation; University of Montana, Missoula

The Wildlife Society should oppose the transfer of federal lands to the states or their sale to private interests. Federal public land and the wildlife it supports is in the national interest and is essential to the conservation of biological diversity. Those interests advocating the transfer of federal lands to the states have still yet to explain how transferred lands would be managed. These unanswered questions have significant implications for wildlife conservation and the management of habitat. Managing federal public land in a democracy comes with its challenges. The solution is not to transfer federal lands to the states or sell them to private interests or to backslide on foundational federal land and environmental laws. The more constructive approach is to seriously investigate ways in which these laws can be more effectively and efficiently implemented.

Sagebrush Stories

Bok Sowell, Department of Animal and Range Sciences, Montana State University, Bozeman
Mike Frisina, Department of Animal and Range Sciences, Montana State University, Bozeman
Carl Wambolt, Department of Animal and Range Sciences, Montana State University, Bozeman

Wildlife habitat management approaches are often based on success stories we like. The justification for using fire to control juniper encroachment of sagebrush in western Oregon is well founded. Application of this approach in western Montana can have long term negative consequences because the recovery time of our plant species are much slower. Improving sage-brush habitats with fire appeals to our sense of stewardship, even though most sagebrush taxa do not have any evolutionary adaptations to fire. Management suggestions taken from other areas for residual grass heights do not match the vegetation of sage-grouse core areas in Montana because of differences in climate and plant species. Some managers suggest we need to reduce sagebrush cover to promote forb production even though this relationship has not been demonstrated in many places in Montana. We are drawn to stories that are simple and that share our view of the world. Improved management begins when we test these stories.

Presentation Abstracts

In Order of Presenting Author
*** Denotes Presenter**
****indicates student presentation**

Surveillance Strategy for Detecting Pseudogymnoascus Destructans (PD) and White-Nose Syndrome in Montana 2016-2017

Emily Almberg*, Montana Fish Wildlife and Parks, Bozeman
Dan Bachen, Montana Natural Heritage Program, Helena
Lauri Hanauska-Brown, Montana Fish Wildlife and Parks, Helena

The devastating bat disease, White-Nose Syndrome (WNS), caused by the fungus *Pseudogymnoascus destructans* (*Pd*), was detected in western Washington state in March of 2016. This detection was 1,300 miles from the previous westernmost detection and highlighted the urgency for surveillance in other western states like Montana. Early detection of the disease may provide valuable insights into the statewide status of WNS, research opportunities, mitigation options and cave management. The goals of Montana's surveillance plan include 1) surveying for WNS/Pd in new geographic areas outside the WNS-affected zone and/or biologically important sites and 2) surveying for WNS infection in bat species that are not currently known to be susceptible. In the absence of information or a risk assessment to help Montana focus on priority surveillance areas other than winter hibernacula, the 2017 strategy focuses on sampling at six hibernacula representing all regions where aggregations of bats overwinter. Both active and passive sampling of bats and hibernacula environments will be conducted. Active sampling can detect Pd from swabs of bats or in hibernacula soils. Passive sampling will be conducted into the early summer specifically targeting bats found dead outside of hibernacula, bats showing clear signs of WNS infection, and bats found dead as part of a large mortality event. Bats submitted for rabies testing may also be sampled when circumstances or characteristics of the carcass indicate WNS may be the cause of mortality. While surveillance efforts can be costly it may provide information with enough time to better inform decision making.

Modeling Management Strategies for the Control of Bighorn Sheep Respiratory Disease

Emily Almberg*, Montana Fish Wildlife and Parks, Bozeman
Kezia Manlove, Washington State University, Pullman
Frances Cassirer, Idaho Department of Fish and Game, Lewiston
Jennifer Ramsey, Montana Fish Wildlife and Parks, Bozeman
Keri Carson, Montana Fish Wildlife and Parks, Bozeman
Justin Gude, Montana Fish Wildlife and Parks, Helena
Raina Plowright, Department of Microbiology & Immunology, Montana State University, Bozeman

Infectious pneumonia has plagued bighorn sheep populations and stymied recovery efforts across the western United States for decades. Here we present a simple, non-spatial, stochastic, discrete-time model that captures basic bighorn sheep demographics and in which we simulate the dynamics of *Mycoplasma ovipneumoniae*, the suspected primary causative agent in bighorn sheep respiratory disease. We then use the model to explore the impacts of

management approaches, including augmentation, depopulation and reintroduction, density reduction, and test-and-cull, aimed at reducing or eliminating the pathogen, its transmission, or associated infection costs. Results suggest that test-and-cull (testing 95% of a herd and removing PCR-positive individuals) and depopulation and reintroduction (assuming ability to only depopulate 95% of the herd) offer the best probability of eliminating the pathogen, although neither are expected to be 100% successful. Augmentation (adding 30 adult ewes) does not increase the probability of pathogen extinction, and in some cases may prolong pathogen persistence and diminish herd recovery. Density reduction (randomly removing 25-50% of the herd) only modestly increases the probability of stochastic pathogen extinction and herd recovery. Stochastic pathogen extinction and herd recovery is predicted to occur on occasion without any management intervention. Ultimately, decisions to manage respiratory disease in wild sheep must weigh the predicted success of the management tool against financial, logistical, ethical, and value-based considerations. Here, we aim to supply mechanistic-based predictions of the relative efficacy of currently employed or proposed tools, as well as characterize the sensitivity of these predictions to our assumptions about how the disease process works.

Challenges with Sampling Sage Grouse Leks and Interpreting Population Trends in Central Montana

Sonja S. Andersen*, Montana Fish Wildlife and Parks, Lewistown

Estimating population size and monitoring trends over time is a fundamental task for management biologists. For species of conservation concern like the Greater sage-grouse (*Centrocercus urophasianus*), using robust methods to monitor populations is imperative. Biologists usually monitor sage-grouse by surveying males at breeding leks each spring. Over 1700 sage-grouse leks exist in Montana, presenting a formidable logistical challenge to census given their accessibility, timing of activity, and other constraints. Thus, not all leks get surveyed each year. In 2005, Montana Fish, Wildlife, and Parks designated 88 Adaptive Harvest Management (AHM) leks to prioritize survey efforts and undergo a more rigorous, consistent sampling protocol; these counts are considered the best indicator of sage-grouse population trends in Montana. However, AHM leks do not provide a random sample required for strong statistical inference, and may not be representative of the remaining leks in an area. I compared count data between AHM and non-AHM leks near Lewistown, Montana, finding mean males/lek is significantly higher on AHM leks than non-AHM leks. Additionally, these larger AHM leks appear to persist longer than smaller leks, which may indicate a minimum size (or potential Alee effect of sorts) at which a lek is more likely to fail. A Cox proportional hazards model indicates differences in survivability across lek size classes (i.e., the hazard of a lek failing is 11.48 times greater for the smaller leks than the larger leks). Given these observations, sampling only AHM leks may predispose us to incorrectly interpreting sage-grouse population status across the state.

Bat Use, Human Visitation, and Environmental Attributes of Cave Hibernacula in Montana

Daniel Bachen*, Montana Natural Heritage Program, Helena
Bryce Maxell, Montana Natural Heritage Program, Helena
Lauri Hanauska-Brown, Montana Fish, Wildlife and Parks, Helena

Across the eastern United States, caves historically supported large aggregations of overwintering bats. In contrast, few large aggregations have been observed within caves in Montana. To collect comprehensive information on cave use by bats and inform White Nose Syndrome surveillance, we inventoried caves to estimate numbers of hibernating bats, assessed the microclimate within hibernacula, monitored activity of bats using acoustic detectors, and quantified visitation by people using trail cameras. In collaboration with recreational cavers, state, and federal biologists we conducted over 300 structured and incidental surveys at 99 caves. Only 6 caves had counts exceeding 100 individuals, and our largest hibernacula had approximately 1,700 bats. The mean annual temperature and humidity across 16 caves averaged 5.0°C and 100% RH. At the 6 largest hibernacula, we established year round baselines of bat acoustic activity and quantify visitation by people. We found that both the number of people entering caves and bat activity within caves peaked in summer. During the winter, visitation appears largely dependent on accessibility of the cave and all monitored caves had low levels of bat activity. Caves in Montana appear to support relatively few aggregations of overwintering bats. Although we have visited most known caves in the state, the number of hibernating individuals we observed is likely orders of magnitude less than the total number we presume overwinter in-state. Future projects should explore the use of cracks, crevices, talus, and badlands to identify other important hibernacula.

Rediscovery of the Northern Myotis in Montana

Daniel Bachen*, Montana Natural Heritage Program, Helena
Bryce Maxell, Montana Natural Heritage Program, Helena
Mike McGrath, US Fish and Wildlife Service, Helena, MT
Brandi Skone, Montana Fish Wildlife and Parks, Miles City
Heather Harris, Montana Fish Wildlife and Parks, Glasgow

The Northern Myotis aka: Northern Long-eared Bat (*Myotis septentrionalis*, NLEB) may be among the rarest mammal species within Montana. Prior to 2016 its presence in the state was known from a single male collected from an abandoned coal mine south of Culbertson, MT in the winter of 1978. In 2015 this species was listed as Threatened under the Endangered Species Act because of significant declines in eastern populations due to White-Nose Syndrome (WNS). To provide information about the presence and distribution of this species within the state, we conducted mist netting surveys in 2015 and 2016 across 9 counties designated by the US Fish and Wildlife Service as part of the NLEB's range. In 2015, forested uplands and deciduous forest were targeted over 11 nights. In 2016, we targeted deciduous forest along major river drainages for 23 nights. We captured 3 NLEBs at 2 sites in 2016 and 0 in 2015. All Myotis species were genetically confirmed. Individuals were captured at 2 sites along the Missouri river in proximity to the previous detection in Montana and historic records in North Dakota. Both females and the male were reproductive, indicating that this species may breed within the state. However, given the close proximity to the border of the female captures, we cannot definitively say whether these animals roost in North Dakota or Montana. In addition to captures of NLEBs we also established records for several WNS susceptible species, providing valuable pre-WNS baseline information on bats in this region.

**Nutritional and Demographic Consequences of Varying Elk Migratory Behaviors

Kristin J. Barker*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Kelly M. Proffitt, Montana Fish Wildlife and Parks, Bozeman
Jesse Devoe, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Michael S. Mitchell, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Craig Jourdonnais, MPG Ranch, Missoula, MT
Philip Ramsey, MPG Ranch, Missoula, MT

Elk (*Cervus elaphus*) populations in the American West exhibit wide variation in migratory behavior. The traditional view of elk migration holds that migratory elk move from winter range in order to track growth of highly nutritious fresh vegetation into higher elevation areas. Non-migratory elk forego this seasonal movement, typically foraging in lower elevation winter range areas throughout the summer. Although the effect of summer nutrition on elk body condition and reproductive success is well known, the nutritional and demographic consequences of these differing migratory behaviors remain unclear. We developed a predictive model of summer forage quality to compare the nutrition available to migrants and non-migrants in a partially migratory population of elk in western Montana. Non-migratory elk had access to significantly higher forage quality than their migratory counterparts; the lower forage quality available to migrants is predicted to result in reduced reproductive success based on published studies linking nutrition with elk demographic rates. We therefore expect non-migrants to have higher fecundity rates and to comprise a higher proportion of the population relative to migrants. Harvest management actions that reduce survival rates of non-migrants or increase survival rates of migrants may be an effective tool for maintaining migratory behavior in partially migratory populations.

**Immigration as a Compensatory Mechanism to Offset Harvest Mortality in Harvested Wolf Populations

Sarah B. Bassing*, Montana Cooperative Wildlife Research Unit, Missoula
David E. Ausband, Idaho Department of Fish & Game, Coeur d'Alene
Michael S. Mitchell, USGS Montana Cooperative Wildlife Research Unit, Missoula
Michael K. Schwartz, USFS Rocky Mountain Research Station, Missoula, MT
Lisette P. Waits, University of Idaho, Moscow

In less than a decade the U.S. Northern Rocky Mountain gray wolf (*Canis lupus*) population has experienced large shifts in management practices, from federal protection under the Endangered Species Act to increasingly liberal hunting and trapping seasons in many portions of their range after delisting. As a result, there is interest in how current wolf management practices will affect this population over time. Recent research suggests wolf pup recruitment in central Idaho has declined since harvest was initiated, yet wolf densities appear stable in many regions of the state, suggesting other compensatory mechanisms are offsetting the effects of harvest mortality. Our objective was to evaluate immigration as a compensatory mechanism that may offset the effects of harvest mortality and facilitate population persistence in a heavily harvested wolf population. Using noninvasively sampled DNA we identified dispersers into two focal study areas in central Idaho prior to and after harvest was initiated. We measured genetic relatedness within and among wolf packs using three different metrics to assess how immigration has changed with changing management practices. Our results suggest that at current harvest rates immigration is not acting as a

compensatory mechanism to offset the effects of harvest mortality. Local dispersal may be unaffected by harvest pressure whereas harvest has negative effects on long-distance dispersal. Our research can help managers consider the effects of immigration on local wolf populations when making harvest management decisions.

Timing, Duration, and Pathways of Harlequin Duck Migration to Pacific Molting and Wintering Areas

Lisa J. Bate*, National Park Service, Glacier National Park, West Glacier, MT
Chris Hammond, Montana Fish Wildlife and Parks, Kalispell
Lucas Savoy, Biodiversity Research Institute, Portland, ME
Sean Boyd, Environment and Climate Change Canada, Delta, BC
Beth MacCallum, Bighorn Wildlife Technologies, Hinton, AB
Malcolm McAdie, DVM, Nanaimo, BC
Matt Wilson, Washington Department of Fish and Wildlife, Lakewood
Joseph Evenson, Washington Department of Fish and Wildlife, Lakewood
Susan Patla, Wyoming Game and Fish Department, Jackson

The core breeding range for Harlequin Ducks (*Histrionicus histrionicus*) in western North America extends from Alaska, and south through the Yukon, Northwest Territories, and British Columbia. Smaller breeding populations exist in southwestern Alberta, Washington, Oregon, Idaho, Wyoming, and Montana. Each state and province in these areas has identified the Harlequin Duck as a species of conservation priority, given its small and isolated populations, its specific nesting requirements, and changes in abundance or distribution. Conservation objectives for all areas have identified the importance of mapping migration routes that connect breeding sites to Pacific coast molting and wintering locations, as well as determining migration timing, duration, habitat use, and stopover sites. In spring 2016, we captured Harlequin Duck pairs on breeding streams and surgically implanted satellite transmitters in the males and attached geolocators to the leg bands of females. We marked 18 harlequin pairs (Alberta = 10 (minus one female), Montana = 5, Wyoming = 2, Washington = 1). Migration initiation dates varied by breeding areas and occurred from June 3 to July 10. Male migration lasted between 1-17 days and stopovers occurred approximately half-way to the coast and included rivers, mountain streams, and lakes. They arrived at their molting areas between June 5-July 24 and these areas ranged from southeast Alaska to northwestern Washington. The majority (71%) of harlequins departed molt locations to differing winter locations. Efforts will be made to retrieve the geolocators from females in spring 2017 to compare locations between males and females from different devices.

Restoration of Trumpeter Swans on the Flathead Indian Reservation and Adjacent Aboriginal Lands in Northwestern Montana

Dale M. Becker*, Confederated Salish and Kootenai Tribes, Pablo, MT
Jocelyn L. Aycrigg, Department of Fish and Wildlife Sciences, University of Idaho, Moscow

In an effort to restore extirpated native wildlife to the Flathead Indian Reservation (FIR) and aboriginal lands in western Montana, the Confederated Salish and Kootenai Tribes (CSKT) commenced reintroduction and restoration efforts for Trumpeter Swans in 1996 with a trial reintroduction. Since then, 264 captive-propagated Trumpeter Swans were released on the FIR from 2002 through 2016. By 2004, breeding pairs had formed and the first production of wild cygnets in possibly 100 years or more fledged from local wetlands. During

the intervening years, at least 119 nesting pairs have produced at least 343 fledgling cygnets. Swans from this project have colonized into several wetland habitats throughout northwestern Montana and may soon do the same in southeastern British Columbia. The primary cause of mortality of released swans has been powerline collisions, and lines are regularly marked with flight diverter installations to minimize potential future collisions. Since annual surveys seemed to indicate a healthy, growing population of Trumpeter Swans in northwestern Montana, the CSKT contracted for a population viability analysis with the University of Idaho to assess overall success of the project and the prognosis for the population to continue to thrive. The results of that analysis indicated that, although the population was predicted to have a low likelihood of persistence, the short time span of data in which adults successfully fledged a brood was increasing (since 2012) was likely a factor in that result. Projecting this analysis into the future, thereby extending the time span of data, indicated that the likelihood of the population persisting was high (approximately 95-96%) over both the short-term (30 years) and the long-term (100 years). As additional population surveys are conducted over the years, the long-term data will better estimate the likelihood of reaching the objectives of long-term sustainability in the future.

**Use of Camera Collars to Reassess the Foraging Strategies of Bears in Yellowstone National Park

Nathaniel R. Bowersock*, Department of Ecology, Montana State University, Bozeman
Andrea R. Litt, Department of Ecology, Montana State University, Bozeman
Kerry Gunther, Yellowstone Center for Resources, Yellowstone National Park, WY
Frank T. van Manen, USGS Northern Rocky Mountain Science Center, Bozeman, MT

Black bears and grizzly bears are opportunistic omnivores that consume a seasonally dynamic diet that varies over time and space. Changes in climate may influence the abundance and distribution of foods consumed by bears, which may place bears in closer proximity to humans and increase human-bear interactions. Therefore, reliable data on bear diets will remain important information for managers. Previous studies of bear foraging relied on visiting locations from GPS collars and documenting bear activity, but evidence of activity or foraging was observed at only 30–50% of locations. Emerging technologies, such as GPS camera collars, can provide new insights into the ecology of cryptic animals, including bears, and could be used to better understand the dynamic nature of their diets. During 2014–2016, we deployed GPS camera collars on 3 grizzly bears and 3 black bears in Yellowstone National Park as a pilot study to gain insights about the nutritional ecology of these species. Field crews observed sign of bear activity at ~52% of the GPS locations searched, which is comparable to other studies. However, when we compared the sign found by field crews to videos recorded by the collars at the same locations, the two methods matched only 18.6% of the time. This low congruence demonstrates a need to improve methods to understand foraging activities. Inference may be improved by matching rich datasets from GPS-tracking devices (i.e., location information and accelerometer data) with video documentation to predict bear foraging behaviors.

Predicted Suitable Habitat Modeling for Species of Concern in Montana

Braden Burkholder*, Montana Natural Heritage Program, Helena
Bryce Maxell, Montana Natural Heritage Program, Helena

Predicted suitable habitat models can be valuable and informative tools for species management and conservation, especially for rare or infrequently documented species. For nearly ten years, the Montana Natural Heritage Program (MTNHP) has produced predicted suitable habitat models for use by agency personnel, researchers, and the general public with the goal of predicting the distribution and relative suitability of habitat for those species. These models are produced using maximum entropy modeling (Maxent), a method of inductive modeling that is robust to small sample sizes. Recent advances in automation by MTNHP using Python and templated reports have decreased the time required for model production more than tenfold, allowing for the publication of models for all terrestrial vertebrate Species of Concern (SOC). Models for SOC can now be updated whenever valuable new data become available due to the costs and time saved by automation. Simplified results for most models have been incorporated into standard environmental summary products at MTNHP in the form of potential species lists for SOC within a grid of one square mile hexagons. Models for non-Species of Concern will be developed as staff time and funding allow, but should be very affordable (e.g., circa $250 per species).

Imperfect Tests, Pervasive Pathogens, and Variable Demographic Performance: Thoughts on Managing Bighorn Sheep Respiratory Disease

Carson J. Butler, Ecology Department, Montana State University, Bozeman
W. Hank Edwards, Wyoming Game and Fish Department, Laramie
Jessica Jennings-Gaines, Wyoming Game and Fish Department, Laramie
Halcyon J. Killion, Wyoming Game and Fish Department, Laramie
Mary E. Wood, Wyoming Game and Fish Department, Laramie
J. Terrill Paterson, Ecology Department, Montana State University, Bozeman
Kelly M. Proffitt, Montana Fish Wildlife and Parks, Bozeman
Emily S. Almberg, Montana Fish Wildlife and Parks, Bozeman
P.J. White, Yellowstone National Park, Mammoth, WY
Douglas E. McWhirter, Wyoming Game and Fish Department, Cody
Jay J. Rotella, Ecology Department, Montana State University, Bozeman
Robert A. Garrott*, Ecology Department, Montana State University, Bozeman

Respiratory disease (pneumonia) has been a persistent challenge for bighorn sheep (*Ovis canadensis*) conservation and its cause has been attributed to numerous bacteria including Mycoplasma *ovipneumoniae* and several *Pasteurellaceae* family species. This study sought to investigate efficacy of diagnostic protocols in detecting *Pasteurellaceae* and Mycoplasma *ovipneumoniae*, generate sampling recommendations for different protocols, assess the distribution of these disease agents among 17 bighorn sheep populations in Montana and Wyoming, and evaluate what associations existed between detection of these agents and demographic performance of bighorn sheep populations. Analysis of replicate samples from individual bighorn sheep revealed that detection probability for regularly-used diagnostic protocols was generally low (<50%) for *Pasteurellaceae* and was high (>70%) for Mycoplasma *ovipneumoniae*, suggesting that routine pathogen sampling likely mischaracterizes respiratory pathogen communities. Power analyses found that most pathogen

species could be detected with 80% confidence at the population-level by conducting regularly-used protocols multiple times per animal. Each pathogen species was detected in over half of the study populations, but after accounting for detection probability there was low confidence in negative test results for populations where *Pasteurellaceae* species were not detected. Seventy-six percent of study populations hosted both Mycoplasma ovipneumoniae and *Pasteurellaceae* pathogens, yet a number of these populations were estimated to have positive population growth rates and recruitment rates greater than 30%. Overall, the results of this work suggest that bighorn sheep respiratory disease may be mitigated by manipulating population characteristics and respiratory disease epizootics could be caused by pathogens already resident in bighorn sheep population.

Protecting Spirit of Place: Reconstructing Highways, Maintaining Habitat Connectivity, and Respecting Tribal Culture

Whisper Camel-Means*, Confederated Salish and Kootenai Tribes, Pablo, MT
Marcel P. Huijser, Western Transportation Institute, Montana State University, Bozeman
Dale Becker, Confederated Salish and Kootenai Tribes, Pablo, MT

The US Highway 93 North reconstruction project on the Flathead Reservation in represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile long road section included the installation of wildlife crossing structures and wildlife exclusion fences. The mitigation measures were aimed at improving safety for the traveling public through reducing wildlife-vehicle collisions, while simultaneously allowing wildlife to continue to move across the road. These measures were an integral part of the reconstruction of this highway because the Confederated Salish and Kootenai Tribes required the reconstructed highway to be respectful of the land, the people and their culture, and wildlife. This project provided an opportunity to evaluate the extent these mitigation measures helped improve human safety through a reduction in wildlife-vehicle collisions; and maintain habitat connectivity for wildlife. Wildlife-vehicle collision data were obtained from Montana Department of Transportation. Completed wildlife crossing structures were monitored for wildlife movements between 2010 and 2015 using wildlife cameras (Reconyx, PM35 and PC900 HyperFire). The reconstruction of US 93 North improved human safety in general along the entire transportation corridor between Evaro and Polson. The total number of reported crashes decreased by approximately 33%. However, the number of reported wildlife-vehicle collisions did not decrease over the entire length of the highway between Evaro and Polson. Total wildlife use of the 29 crossing structures that were monitored can be described as substantial with 95,274 successful crossings in total, and 22,648 successful crossings per year.

Hemorrhagic Disease in Montana's Wild Ruminants

Keri Carson*, Montana Fish Wildlife and Parks, Bozeman
Emily Almberg, Montana Fish Wildlife and Parks, Bozeman
Jennifer Ramsey, Montana Fish Wildlife and Parks, Bozeman

Epizootic hemorrhagic disease and bluetongue virus have been documented in Montana for decades. Montana has experienced localized and variable population declines in wild cervids when these outbreaks occur. Transmission is seasonal in North America, with infection occurring in the late summer and fall. In northern states, transmission ends once adult vectors cease activity with the onset of winter. Montana is in an epidemic zone where outbreaks appear periodically and mortality events can be significant. Montana Fish, Wildlife

and Parks wildlife health lab has tested samples from suspected outbreak events, research captures and opportunistically for detection of EHD and BTV. Environmental factors and virus-vector-host interactions are knowledge gaps that need to be addressed to improve our understanding of these orbivirus dynamics. Enhanced reporting, surveillance, and research efforts are potential tools that may improve our understanding of the role these viruses play in wild ruminant populations across the state.

Diet and Macronutrient Optimization in Wild Ursids: Grizzly Bears Versus Black Bears

Cecily M. Costello*, College of Forestry and Conservation, University of Montana, Missoula
Steven L. Cain, Grand Teton National Park, Moose, WY
Shannon Pils, USGS Northern Rocky Mountain Science Center, Bozeman, MT
Leslie Frattaroli, Grand Teton National Park, Moose, WY
Mark A. Haroldson, USGS Northern Rocky Mountain Science Center, Bozeman, MT
Frank T. van Manen, USGS Northern Rocky Mountain Science Center, Bozeman, MT

When fed ad libitum, ursids can maximize mass gain by selecting mixed diets wherein protein provides 17 ± 4% of digestible energy. In the wild, this ability is likely constrained. By visiting locations of 37 individuals during 274 bear-days, we documented foods consumed by grizzly (*Ursus arctos*) and black bears (*Ursus americanus*) in Grand Teton National Park during 2004–2006. Based on published data, we estimated foods and macronutrients as percentages of daily energy intake. Using principal components and cluster analyses, we identified 14 daily diet types. Only 4 diets, accounting for 21% of days, provided optimal protein levels. Nine diets (75% of days) led to over-consumption of protein, and 1 diet (3% of days) led to under-consumption. Highest protein levels were associated with animal matter (i.e., insects, vertebrates), which accounted for 46–47% of daily energy for both species. As predicted: 1) daily diets dominated by vertebrates were positively associated with grizzly bears and protein intake was positively associated with body mass; 2) diets dominated by fruits were positively associated with black bears; and 3) mean protein was highest during spring, when high-energy foods were scarce, however it was also higher than optimal during summer and fall. Although optimal gain of body mass was constrained, bears opted for the energetically superior trade-off of consuming high-energy, high-protein foods. Given protein digestion efficiency similar to obligate carnivores, this choice likely supported mass gain, consistent with studies showing monthly increases in percent body fat among bears in this region.

The Northwest Section of the Wildlife Society and Montana: Past, Present, and Future

Julie A. Cunningham*, Montana Fish, Wildlife and Parks, Bozeman
Scott Brainerd*, Alaska Department of Fish and Game, Fairbanks, AK

At this 2017 meeting of the Northwest Section and the Montana Chapter of The Wildlife Society, this talk will present the past, present, and potential futures of the Northwest Section as it relates to Montana and to the Parent Society. Many members today will remember the Section's dedicated meetings and high level of professional involvement and wonder "where are we now?" For others, this talk may be their introduction to the Section and how to be involved. The Northwest Section has shared deep roots with our Montana wildlife heritage, with common leaders and common vision, since the inception of our profession. Originally composed of Montana, Alaska, Oregon, Washington, Idaho, British Columbia, and Alberta, the Section had powerful and well-attended annual meetings with themes including

foundational concepts in game bird and big game population and habitat management and policy. Professionals representing an array of agencies, entities, and universities gathered to share the latest scientific findings, mentor students, and address environmental challenges. A Parent Society reorganization in the early 2000's lead to formation of a Canadian Chapter and the Section lost connection with British Columbia and Alberta. Since that time, the Section has been through a period of reformation. With well-represented member states, an enthusiastic board, and increased dues, the Section's vision for the future is bright. Future directions will include focus on building student chapters and bringing student conclaves to the Northwest, supporting policy stances on issues that cross state lines, and increasing communication between our member states.

**Harvest and Non-harvest Mortality Relationships for Lesser Scaup Breeding in Southwestern Montana

Cody E. Deane*, Department of Ecology, Montana State University, Bozeman
Jay J. Rotella, Department of Ecology, Montana State University, Bozeman
Jeffrey M. Warren, USFWS Region 6 National Wildlife Refuges, Lima, MT
David N. Koons, Wildland Resources Department, Utah State University, Logan
Robert R. Garrott, Department of Ecology, Montana State University, Bozeman

Since the mid-to-late 1990s, lesser scaup (*Aythya affinis*) populations have remained more than 20% below the population goal set forth in the North American Waterfowl Management Plan. Accordingly, considerable attention has been directed towards understanding what factors may be limiting their population, including the role of harvest. Red Rock Lakes National Wildlife Refuge (RRL) in southwestern Montana is the site of a long-term study of lesser scaup ecology and demography with data from which survival and harvest rates can be estimated using capture-mark-recapture statistical techniques. The role of harvest in regulating duck population dynamics, including lesser scaup, is clouded with uncertainty. Decades of research into the additive or compensatory nature of harvest mortality has yielded little consensus as to which of these hypotheses prevail in North American duck populations. The most limiting factor to assessing these relationships stems from lacking estimates of population size during waterfowl hunting seasons. We assessed the relationship between survival rates and harvest rates for lesser scaup females breeding at RRL for an 11 years, beginning in 2005. Consistent with predictions of density dependence regulation of natural mortality rates during the non-breeding season, we found evidence suggesting adult female survival rates fluctuate in response to harvest regulations, an index of population size, and the total number of lesser scaup harvested in the Pacific and Central Flyways.

Occupancy Modeling of Hunter Sightings for Monitoring Moose in Montana

Nicholas J. DeCesare*, Montana Fish Wildlife & Parks, Missoula
Jesse R. Newby, Montana Fish Wildlife & Parks, Kalispell
Kevin M. Podruzny, Montana Fish Wildlife & Parks, Helena
Keri Wash, Montana Fish Wildlife & Parks, Bozeman
Justin A. Gude, Montana Fish Wildlife & Parks, Helena

Moose (*Alces alces*) are widely distributed across >100,000 km2 of Montana yet occur at low densities and garner minimal funding. Traditional monitoring methods present challenges of low precision and high cost. During 2012–2015, we tested the efficacy of applying patch occupancy modeling to moose sightings made by hunters of other cervids for cost-effective statewide monitoring. We used phone surveys to collect sightings and allocated each

spatially to grid cells and temporally to 1-week sessions within a 5-week hunting season. For each cell we estimated covariates with hypothesized relevance to occupancy by moose or detectability by hunters, including characterization of vegetation, topography, accessibility by humans, hunter effort, and spatial correlation. We sampled ≥45,500 hunters per year at a cost of $12,000–$15,000. Of responding hunters, 14% reported ≥1 moose sighting which accumulated to 4,800–6,800 sightings annually. Statewide occupancy estimates were robust and consistent across years of sampling, averaging $\Psi = 0.30$ (SE=0.005, range=0.30–0.31). Forested vegetation types reduced the probability of detection but increased the probability of occupancy, while shrub and riparian vegetation types increased both detection and occupancy rates. The amount of sampling effort expended affected detection rates but did not affect occupancy estimates. We expect occupancy estimates to be less sensitive to population changes in areas with higher abundance, making this approach better suited for monitoring change at the range periphery. Alternate count-based analysis techniques such as n-mixture models may offer an alternative to make best use of hunter sightings for monitoring statewide moose populations.

Fire and Forage: Variability in Elk Forage on a Landscape of Wildfire and Changing Fire Management

Jesse DeVoe*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Kelly M. Proffitt, Montana Fish Wildlife and Parks, Bozeman
Kristin Barker, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Rebecca Durham, MPG Ranch, Missoula, MT
Teagan Hayes, MPG Ranch, Missoula, MT
Mark Hebblewhite, Dept of Ecosystem and Conservation Sciences, University of Montana, Missoula
Craig Jourdonnais, MPG Ranch, Missoula, MT
Philip Ramsey, MPG Ranch, Missoula, MT
Julee Shamhart, Montana Fish Wildlife and Parks, Bozeman

Forest management practices can modify ungulate nutritional resources through landscape-scale processes such as prescribed fire and wildfire. The resulting availability and distribution of nutritional resources can affect ungulate survival, reproduction, and distribution. Our primary goals were to evaluate how landscapes with varying post-fire successional stages influence elk summer nutritional resources and to quantify the variability of nutritional resources associated with varying fire histories and management practices during 1900–2015. Within 3 elk population ranges located in the Bitterroot Valley, Montana, we measured elk forage quality across a range of land cover types and fire histories and developed a landscape-scale forage quality model. Based on historical wildfire and prescribed fire data, we reconstructed decadal land cover models and used our forage models to predict fire-related variations in forage quality each decade within the elk summer ranges. Forage quality was predicted to decrease with successional stage. The area burned by wildfire increased 242–1,772% during 1990–2015 as compared to 1900–1990, resulting in fire-related variations of predicted nutritional resources. The area of highest forage quality varied, increasing 31.3–48.5% in 2 ranges and decreasing 2.4% in 1 range, from 1900–1990 to 1990–2015. These results highlight the important effect of wildfire on the distribution of ungulate nutritional resources and demonstrate that ungulate nutritional resources likely vary over time with variation in fire history and management practices.

Tracking New Species: An Update on Satellite Telemetry Data from Raptors Captured on the MPG Ranch

Robert Domenech*, Raptor View Research Institute

We have studied the fall migration of raptors at the MPG Ranch near Florence, Montana, since 2011. Our banding efforts during this period have yielded modest totals, but impressive species diversity, with a relatively high proportion of Red-tailed Hawks and large falcons. After several successful years outfitting Golden Eagles and Ospreys with satellite transmitters, we decided to expand these efforts to other species. To date, we have outfitted 8 Red-tailed Hawks, 4 Cooper's Hawks, 3 Peregrine Falcons and 1 Prairie Falcon with satellite transmitters captured on the MPG Ranch during fall migration. We will share what we've learned from these individuals and give a telemetry update on our Osprey study.

Climatic Data for Wildlife Research and Management

Phil Farnes*, Snowcap Hydrology, Bozeman, MT

There is generally a poor correlation between climatic variables at lower elevations and higher elevations. It is imperative that this relationship be understood when evaluating climatic effects on species that move from lower to higher elevation during different seasons. It is also important that valley climatic conditions are not used to define relationship of species that occupy higher elevations. Using data from NRCS SNOTEL (SNOw TELemetry) sites and NWS climatic stations can help define climatic conditions at locations occupied by concerned species. Daily data is generally more useful than monthly or seasonal averages. There are approximately 90 SNOTEL sites across Montana that typically report daily SWE (snow water equivalent), precipitation, maximum, minimum and average temperatures year-around and data is available in real-time. SWE can be related to travel, soil temperature, forage production and availability, migration and predator-prey relationships. Some SNOTEL sites also report snow depth. NWS stations typically report daily precipitation, maximum and minimum temperature but data for most stations is reported monthly. SWE can be estimated for NWS sites where daily air temperature, snow depth and precipitation are reported. Precipitation can be related to forage production, soil moisture and fall green-up. Maximum, minimum and average daily temperature can be related to forage production, phenology, the day plants break dormancy, fall green-up, critical temperatures for animals. Annual variability as well as elevational variability can be used to refine data to each area of interest. Some examples of the relationships described above will be presented.

Mule Deer Management in Southeastern Montana

Melissa A. Foster*, Montana Fish Wildlife and Parks, Baker
Ryan M. DeVore*, Montana Fish Wildlife and Parks, Broadus
Dean J. Waltee, Montana Fish Wildlife and Parks, Sheridan
John T. Ensign, Montana Fish Wildlife and Parks, Miles City

In 1982, Montana Fish, Wildlife and Parks Region 7 implemented a five week regionwide general license either-sex plus additional antlerless B license harvest structure for mule deer (*Odocoileus hemionus*). This harvest strategy implemented three important changes from previous years. First, the regionwide harvest structure eliminated the use of small hunting districts and allows the law of diminishing returns to operate: hunters tend to avoid areas with low deer numbers and focus on areas with higher densities. Second, general licenses were made either-sex, rather than antlered-only for mule deer. Third, following natural population

declines (e.g., due to severe natural stressors), biologists began increasing antlerless quotas soon after populations began to recover, rather than waiting until populations were at or above long-term averages. This management system has maximized opportunity and flexibility for hunters while simplifying regulations and enforcement. In the 30-plus years since implementation, Region 7 has seen a reduction in game damage complaints, and an increase in buck-to-doe ratios. Mule deer populations and harvest have been stable long-term, and population fluctuations have decreased in magnitude. This harvest strategy has produced similar results in both Region 7 as a whole (75% private lands) and on the Custer National Forest, a 436,000-ac block of public land.

Comparing Bird Population Trends in the Badlands and Prairies Using BBS and IMBCR Data

T. Luke George*, Bird Conservancy of the Rockies, Fort Collins, CO
Adam Green, Bird Conservancy of the Rockies, Fort Collins, CO
David Pavlacky, Bird Conservancy of the Rockies, Fort Collins, CO
Matthew McLaren, Bird Conservancy of the Rockies, Fort Collins, CO

We compared the direction and precision of trend estimates of bird species in the Badlands and Prairie Bird Conservation Region (BCR 17) from 2009-2015 using Breeding Bird Survey (BBS) and Integrated Monitoring in Bird Conservation Regions (IMBCR) data. We used Bayesian modeling estimates provided by the BBS and newly developed Bayesian estimates of IMBCR data. Trend estimates often differed between the two data sets and estimates of precision were generally smaller for IMBCR than for BBS data. In addition, because the BBS estimates do not correct for detection probability, the BBS estimates measure the trend on an index rather than the detection corrected abundance. If the relationship between the BBS index and true abundance is not linear and 1:1, the interpretation of the BBS trend is unclear. Finally, because BBS counts are conducted along roads, species that are attracted to or avoid roads may be over or under counted, respectively. BBS trends can be helpful for examining long-term trends (greater than 20 years) in bird abundance across large regions but only IMBCR trends provide sufficient precision to examine trends at shorter time intervals. IMBCR trends, therefore, are more useful for identifying current factors influencing bird population trends.

Northwest Climate Science Center–Linking Climate Science to Wildlife Management and Conservation

Betsy Glenn*, Northwest Climate Science Center, Corvallis, OR
Gustavo Bisbal, Northwest Climate Science Center, Corvallis, OR
Nicole DeCrappeo, Northwest Climate Science Center, Corvallis, OR

In 2009, Secretarial Order 3289 (Interior) established eight regional Climate Science Centers (CSC) to "work with other federal, state, tribal, and local governments and private landowner partners to develop landscape level strategies for understanding and responding to climate change impacts." This Order acknowledged that climate-driven changes would likely affect ecosystem function, structure and composition, wildlife populations, and biodiversity in ways that no single management entity could effectively address alone. On-going and emerging ecological changes such as hydrologic regime shifts, invasive species, changes in fire regimes, and land use changes are occurring at spatial and temporal scales that demand a coordinated, inter-jurisdictional approach if we are to mitigate for and adapt to these stressors. The Northwest (NW) CSC has developed approaches to coordinate with regional partners, strategize to identify needed science and capacity, and identify resources to fund

applied research and implement coordinated application to management needs in Washington, Oregon, Idaho, and western Montana. In addition, the NW CSC has developed collaborative partnerships with Federal and state agencies, tribal and intertribal organizations, Landscape Conservation Cooperatives (LCCs), USDA Climate Hubs, and others to provide needed scientific information and tools. This presentation will outline the goals and operational framework of the NW CSC, present case studies of NW CSC climate research used to inform decision-making relevant to wildlife management and conservation across the region, and provide guidance to scientists and managers for identifying actionable science projects that the NW CSC could support for addressing climate-driven changes in ecological systems.

A Multispecies Monitoring Approach for Mesocarnivores in the US Northern Rockies

Jessie D. Golding*, USFS Rocky Mountain Research Station, Missoula, MT
Michael K. Schwartz, USFS Rocky Mountain Research Station, Missoula, MT
Kevin McKelvey, USFS Rocky Mountain Research Station, Missoula, MT
Cara Staab, USFS Northern Region, Missoula, Montana
Scott Jackson, USFS Northern Region, Missoula, Montana
Rema Sadak, USFS Intermountain Region, Ogden, Utah

Mesocarnivores are ecologically important species that are wide-ranging and often difficult to detect. Fisher (*Pekania pennanti*), lynx (*Lynx canadensis*), and wolverine (*Gulo gulo*) (hereafter mesocarnivores) are three mesocarnivores of conservation or management concern native to the US northern Rocky Mountain region (NRM). Federal and state managing agencies in NRM have multiple directives that guide management of these species and their habitats. Fulfilling these mandates is complicated by two overarching problems: 1) gaps in knowledge about the basic distribution, habitat requirements, and spatial and population trends of these mesocarnivores in the region; and 2) the lack of an appropriate, multi-scale framework to analyze the short-term and long-term trends of these species. In response, the USFS is developing a comprehensive mesocarnivore monitoring strategy to meet our mandates for the NRM. These ideas will ultimately be merged with those of our partners. We present the initial phase of this monitoring strategy, a sequential hierarchy that links the following questions to geographic locations: 1) is the species present? 2) are multiple individuals and females present? 3) how many are present? These questions were developed based on a series of structured interviews, as well as past local and regional survey and monitoring efforts for these mesocarnivores. Repeated investigations of these questions over time will allow understanding of changes in distribution and populations of these mesocarnivores in the NRM..

Conflicting Priorities, Competing Interests and Unintended Consequences – Three Decades of Lessons Learned Managing Wildlife Habitat

John C. Grant*, Montana Fish Wildlife and Parks, Charlo

Management of food, cover and water at the Ninepipe Wildlife Management Area (WMA), an intermountain prairie pothole complex in the Mission Valley of western Montana involves many facets beyond decisions to benefit waterfowl and pheasants populations and hunters for which the WMA was established. Interests of WMA users have expanded beyond game species, the mission of Fish, Wildlife & Parks has evolved, and management goals of the WMA program have broadened. This paper describes management approaches and

lessons learned in response to often conflicting priorities and competing interests as the local environment and human values have changed. Pheasants and some waterfowl species have overlapping habitat requirements that serve different life history needs. Habitat features that are good for reproduction and survival are not necessarily the best for hunting. Members of the general public who lobby for their particular interests are not aware of what it takes to get the habitat they think is best. Using farming practices to grow food and nesting cover while conserving and protecting soil, water, and vegetation is the driving goal. Using flood irrigation to manipulate water levels in wetland basins ensures abundant, diverse, and productive habitat. Weed management activities are conducted to improve habitat, whereas habitat improvements are conducted in a manner to minimize the spread of weeds. Trees planted for pheasant winter cover have resulted in grizzly bear/human conflicts – lesson learned! Other lessons include that management practices must be based first on the needs of the natural resources, habitat conditions are fluid and dynamic, great habitat does not necessarily result in high wildlife populations or high hunter satisfaction, and keeping a broad perspective is the best strategy, regardless of short term conditions and pressures. Hopefully the lessons that were learned will be instructive to others managing similar habitats.

Recovering America's Wildlife Act of 2016: What Passage of the Act May Mean to You

Lauri Hanauska-Brown*, Montana Fish, Wildlife and Parks, Helena

The Association of Fish and Wildlife Agencies organized a panel of 26 national business and conservation leaders in 2015 to examine the current system of conservation funding and recommend a new mechanism to conserve all fish and wildlife. Known as the Blue Ribbon Panel on Sustaining America's Diverse Fish and Wildlife Resources, the group recommended Congress dedicate up to $1.3 billion annually in existing revenue from the development of energy and mineral resources to the Wildlife Conservation and Restoration Program. These funds would be awarded to state wildlife management agencies for wildlife related conservation, recreation and education projects. In Montana, the funds would be used to more fully implement State Wildlife Action Plan priorities including on the ground conservation for a broad diversity of species and habitats. Federal House Bill 5650 "Recovering America's Wildlife" act was introduced during the fall of 2016 but needs to be reintroduced in 2017. If passed and fully funded, the federal act could bring $22 million dollars annually to Montana but $7 million dollars in non-federal match will be needed each year. Proactive and partner based projects will be critical to ensure the best use of these funds but prior to that a broad based effort to pass the act is needed. Wildlife enthusiasts, business owners, developers, researchers and others will be needed to argue it is in everyone's best interest to keep species from becoming federally listed and to keep wildlife and habitat healthy.

Drone Technology for Monitoring and Mapping in the Grasslands of Eastern Montana

Jason Hanlon*, Matador Ranch, The Nature Conservancy, Dodson, MT
Charlie Messerly, Matador Ranch, The Nature Conservancy, Dodson, MT
Brian Martin, The Nature Conservancy, Helena, MT
Amy Pearson, The Nature Conservancy, Helena, MT

The Nature Conservancy in Montana has been working to protect wildlife habitat and enhance conservation in the Northern Great Plains for several decades. The foundation of our work has been the Matador Grassbank in south Phillips County. Through the grassbank, ranchers implement conservation practices on their home ranches in exchange for discounted

grazing on the Conservancy's Matador Ranch. One of the conservation practices is the retention of black-tailed prairie dog towns. The southern portion of Phillips County supports among the most acres and largest prairie dog towns in the state. The prairie dog towns in this region of Montana support species of high conservation concern, including two black-footed ferret reintroduction sites, the largest population of mountain plovers, and large numbers of burrowing owls. Discounts for retaining prairie dog towns on grassbank ranches is tiered, based on the size of the town and potential for supporting species of concern. However, precisely mapping towns is challenging when using handheld GPS units and ATV's to traverse the perimeters. Currently, The Nature Conservancy is using drone technology to create more precise and detailed maps. Drones yield detailed imagery which can be incorporated into a GIS, allowing precise mapping of town boundaries. Using drones will enable ranchers and the Conservancy to better understand the expansion or contraction of towns over time. The Matador ranch successfully implemented drone technology as a tool for more efficient and accurate monitoring, and plans to continue incorporating its use in all aspects of conservation and management.

**The Effects of Beetle-Induced Tree Death on Forest Bird Diversity in Western Montana

William M. Janousek*, Avian Science Center, University of Montana, Missoula
Dr. Victoria J. Dreitz, Avian Science Center, University of Montana, Missoula

In forest ecosystems, climate change can hinder management success by increasing the frequency and intensity of fire and insect outbreaks that cause massive tree die-offs and abrupt habitat change. Resource managers often use ecological indicators to gain insight into the health and status of ecosystems due to the challenge of monitoring all aspects of any ecosystem. Birds are increasingly identified as appropriate taxa for predicting changes in biodiversity and ecological integrity around the globe. We assessed the effects of bark beetle induced forest die-off on patterns of avian diversity in western Montana. We used songbirds, which are ubiquitous and possess attributes capturing the complexity of forests as ecological indicators. In addition to assessing the effects of bark beetle forest die-off on bird diversity we also sought to examine the relative importance of the "conspecific neighborhood" in influencing species-level occurrence rates at a given survey location. This approach is motivated by the idea that individuals of a species aggregate around resources. It follows, that a species is more likely to occur in a patch surrounded by other occupied patches (the conspecific neighborhood). Incorporating measures of spatial autocorrelation in ecological studies is not new. However, this topic is only just beginning to be applied in the context of more recent analytical advances such as Bayesian multi-species hierarchal models used to estimate species abundance and occurrence rates.

**Effects of Electric Fence Permeability on Grizzly and Black Bears in the Blackfoot Valley

Brittani Johnson*, Animal and Range Sciences Department, Montana State University, Bozeman
Lance McNew, Animal and Range Sciences Department, Montana State University, Bozeman

Electric fencing is an effective tool for deterring bears from calving areas and bee yards, however scientific evaluations of the impacts of large-scale electric fencing on bear movements and habitat use are lacking. In 2015 and 2016, we conducted a study in the Blackfoot Valley to evaluate A) the efficacy of rapid-deployment electric fencing designs in deterring bears from agricultural lands, and B) landscape level space use and permeability of agricultural lands relative to electric fences. Baited enclosures of 2 fencing configurations

were established in the valley. Each enclosure was systematically energized and unenergized for 3-day periods; passage into the enclosure was monitored with trail cameras to provide information on effectiveness and permeability. In addition, we established 60 randomly selected camera trap stations throughout the valley to evaluate landscape-level use relative to electric fences. Daily locations provided by 4 grizzly bears fitted with GPS collars in 2016 will provide individual-level information on seasonal movements and habitat selection relative to electric fences. The proportion of black bears that were deterred from both configurations of fence when turned on or off over both years was 61% and the proportion that successfully penetrated the enclosures was 38%. The proportion of grizzly bears that were deterred from both configurations of fence over both years was 69% and the proportion that were successful was 30%. The camera traps did not detect enough individuals to conduct a hierarchical occupancy analysis. We will collect the GPS collars in 2017 and conduct an RUF analysis on space use.

How Historical and Current Management Practices have Affected Milk River Riparian Habitat in Northcentral Montana

Kelvin R. Johnson*, Montana Fish Wildlife and Parks, Glasgow
Paul L. Hansen, Ecological Solutions Group LLC, Stevensville, MT
F. Drew Henry, Montana Fish Wildlife and Parks, Glasgow

Riparian and wetland communities support the greatest concentration of plants and animals, yet only constitute 4 percent of Montana's land cover. Because they are more productive than surrounding uplands, they are attractive to livestock and wildlife as they provide important forms of cover and forage. For private and public land managers interested in maintaining long-term integrity and functionality of riparian and wetland communities on their lands, management strategies that accommodate on-site resource needs must be implemented. Determining habitat types and their associated community types on these sites can help identify historical impacts that have affected community type succession, and how current management strategies could be affecting the trend towards one seral stage or another. Both natural and artificial disturbances can affect community type succession, yet succession from one type to another can take several years and even decades. Thus, changes from year to year can be very subtle, and as land managers implement current management practices, they may overlook the visual cues indicating these trends, simply because these processes can be very slow. This presentation summarizes an evaluation of a riparian area located in the Milk River Valley in Northcentral Montana. An illustration of how historical impacts have affected community type succession, and how this site has been affected by a significant change in management practices that occurred over 20 years ago, is provided. Depending on what goals are desired for this site will determine if a change in current management practices is warranted.

Grizzly Bear Restoration in the North Cascades of Washington

Wayne F. Kasworm*, US Fish and Wildlife Service, Libby, MT
Jack Oelfke, North Cascades National Park, Sedro-Woolley, WA
Anne Braaten, North Cascades National Park, Sedro-Woolley, WA
Melissa Stedeford, National Park Service, Denver, CO
Chris Servheen, US Fish and Wildlife Service (Retired) and University of Montana, Missoula

The North Cascades of Washington was one of 6 recovery areas where grizzly bears were known or believed to exist at the time of listing under the Endangered Species Act (ESA) in

1975. The North Cascades recovery plan identified the need for a National Environmental Policy Act process to evaluate a range of alternatives to restore this grizzly bear population. In January of 2017 the Draft Grizzly Bear Restoration Plan for the North Cascades Ecosystem was released for public comment by the National Park Service and the U.S. Fish and Wildlife Service. This plan evaluated four alternatives for population restoration. Alternative A was "No Action" with continued existing management practices focused on improved sanitation, poaching control, motorized access, education, and monitoring to evaluate natural restoration. Alternative B was "Ecosystem Evaluation Restoration" which would transplant up to 10 grizzly bears to the North Cascades and monitor those individuals for 2 years before deciding whether to proceed with additional releases. Alternative C was "Incremental Restoration" in which 5-7 grizzly bears per year would be transplanted to the North Cascades to achieve an initial population of 25 individuals. Monitoring would determine success of the program and the need for additional releases of bears. Alternative D was "Expedited Restoration" in which 5-7 grizzly bears/year would be transplanted to the North Cascades until a population of approximately 200 individuals was achieved. All action alternatives possess an experimental (ESA 10j) population option. The draft document is available for review and comment through March 14, 2017 at: https://parkplanning.nps.gov/projectHome.cfm?projectId=44144

Grizzly Bear Population Trend Estimated Using Genetic Detection

Katherine C. Kendall*, USGS Glacier Field Station, West Glacier, MT
Amy C. Macleod, Wildlife Ecology and Management, University of Alberta, Edmonton, AB
J. Andrew Royle, USGS Patuxant Wildlife Research Center, Laurel, MD
John Boulanger, Integrated Ecological Research, Nelson, BC
Tabitha Graves, USGS, Northern Rocky Mountain Science Center, West Glacier, MT
Kevin S. McKelvey, USFS Rocky Mountain Research Station, Missoula, MT

We use genetic detection data from natural bear rub sites to estimate annual rate of change for a threatened grizzly bear (*Ursus arctos*) population in the 33,300 km2 Northern Continental Divide Ecosystem (NCDE) in northwestern Montana, USA). Bear rubs were surveyed twice annually in 2004, 2009-2012 (3,580 – 4,805 rubs). We detected approximately 1/3 of the grizzly bear population annually. Using spatially explicit capture-recapture (SCR) models in a maximum likelihood framework, we estimate growth rate from the slope of a linear regression fit to the log of density estimates. To evaluate the usefulness of our estimates, we compare them to estimates of λ made using independent data from known-fate telemetry monitoring for our population. Total annual population rate of change was 1.056 (95% CI = 1.033-1.079). The large sample sizes generated by genetic detection provided information on variation in density and trend within the NCDE useful for designing monitoring and management strategies tailored to area-specific needs and priorities. Local rates of change within the NCDE were higher in areas of lower density and population expansion than in Glacier NP, the area with highest density. As density increased, the amount of space used by bears estimated by the SCR models, σ, decreased. Hair collection from natural bear rub sites was an efficient sampling approach able to generate precise estimates of annual growth rate from 2 years of data.

Population Monitoring and Modeling to Enable an Adaptive Management Strategy for Mountain Lions in Montana

Jay Kolbe*, Montana Fish Wildlife and Parks, White Sulphur Springs
Kelly Proffitt, Montana Fish Wildlife and Parks, Bozeman
Josh Nowak, College of Forestry and Conservation, University of Montana, Missoula
Hugh Robinson, Panthera Landscape Analysis Lab, University of Montana, Missoula

Historically, managing harvested mountain lion populations was confounded by the lack of a method to affordably, accurately, and repeatedly estimate a population's size, make rigorous predictions about the effect of future harvest prescriptions, and monitor population trends over time. Managers were unable to fully implement an adaptive mountain lion harvest management program because they lacked the necessary objective monitoring and modeling information. Disagreement about the past, and potential, effects of management decisions led to conflict among stakeholders and with FWP. Montana has now developed a draft mountain lion Management Strategy that will allow FWP to actively monitor statewide mountain lion populations using new genetic spatial capture-recapture field techniques and to routinely extrapolate those local estimates across discrete mountain lion ecoregions using a statistical resource selection function. Managers will then be able to input these population estimates, along with lion demographic parameters (described by regional field research), into a web-based mountain lion integrated population model in order to predict the likely effect of future harvest prescriptions on managed lions across the State. These new monitoring and modeling methods will enable FWP to fully implement an adaptive harvest management program through which population objectives are set, management alternatives are objectively evaluated, a preferred harvest prescription is applied, the effect of that harvest is directly monitored over time, and management is adjusted based on new information and changing objectives. FWP believes that this strategy will help reduce contention among stakeholders, optimize harvest and pursuit opportunity, reduce conflicts, and ensure that robust lion populations are conserved across their Montana habitats.

Simulations Inform Design of Regional Occupancy-Based Monitoring for a Sparsely Distributed, Territorial Species

Quresh S. Latif*, USFS Rocky Mountain Research Station, Bozeman, MT
Martha M. Ellis, Ecology Department, Montana State University, Bozeman, MT
Victoria A. Saab, USFS Rocky Mountain Research Station, Bozeman, MT
Kim Mellen-McLean, USFS Region 6, Portland, OR

Sparsely distributed species attract management concern. Insufficient information on population trends, however, challenges conservation and funding prioritization. Occupancy-based methods are cost effective and therefore attractive for broad-scale trend monitoring, but appropriate sampling design and inference depend on particulars of the study system. We employed spatially explicit simulations to inform regional occupancy-based monitoring of white-headed woodpeckers (*Picoides albolvartus*), a sparsely distributed, territorial species threatened by habitat decline and degradation. We incorporated basic knowledge of species ecology into population simulations to compare statistical power and trend estimation error under alternative scenarios. Sampling effort needed to achieve adequate power to observe a long-term population trend (≥ 80% chance to observe a 2% yearly decline over 20 years) consisted of annually monitoring ≥ 120 transects using the single-survey approach or ≥ 90 transects using a repeat-survey approach. The single-survey approach, which employs occupancy as an index of abundance and requires auxiliary information to account for

detectability, provided more power for a given level of sampling effort than repeat-survey approaches. Alternate allocation schemes improved statistical power and trend estimates over the baseline (surveying 10 points within all transects annually), including surveying a subset (33%) of transects each year (i.e., a panel design) and surveying fewer points per transect in exchange for a larger spatial sample. Considering this case study, single-survey methods (with separate evaluation of detectability), panel designs, and aligning sampling resolution with home range size could likely benefit broad-scale occupancy-based monitoring of other sparsely distributed and mobile species.

Illuminating the Nocturnal Soundscape in the Bitterroot Valley, Montana

Debbie Leick*, MPG Ranch, Florence, MT
Kate Stone*, MPG Ranch, Florence, MT
Craig Kuchel*, MPG Ranch, Florence, MT
Carrie Voss, MPG Ranch, Florence, MT

Darkness hides species on the landscape, but vocalizations illuminate their presence. In a nocturnal soundscape, owls hoot, nighthawks boom, bats echolocate, and insects buzz. Birds that migrate at night emit calls we can record and use for species identification. In 2012, we began to record nocturnal flight calls of migratory birds at three monitoring sites, and by 2016 expanded to eight sites. We have collected and processed over five terabytes of recordings from spring and fall migration. To help us analyze the audio, we customized the open-source software called Vesper. Our archive now includes thousands of detections of species like Wilson's Warbler. In the Bitterroot Valley, this species occurs in low numbers during the breeding season, and are rarely detected during migration by passive observation on the ground. In this presentation, we will share this finding and others from our analysis. We will also discuss efforts to share this acoustic monitoring technique and the Vesper software with local students. Lastly, we will explore some of the ways we can use the recordings to study other acoustic phenomena. A longer-term goal of this project is to develop a network of acoustic monitoring stations across Montana, building a collaboration between interested individuals, non-profits, and managing agencies. We will provide information on how you can participate in this project and attend a training workshop taking place this summer.

Assessing Impacts From One Year of Monitoring at a Wind Farm in Central Montana

Kimberly E. Linnell*, Montana Fish Wildlife and Parks, Great Falls
Dan Bachen, Montana Natural Heritage Program, Helena
Kristina Smucker, Montana Fish Wildlife and Parks, Great Falls
Sam Milodragovich, NorthWestern Energy, Butte, MT

In 2015, NorthWestern Energy, owner of Spion Kop Wind Farm, contracted Montana Fish, Wildlife and Parks to assess impacts on birds and bats and formed a Technical Advisory Committee to guide research and monitoring. An explicit objective was to ensure all methods and results are publicly available. We searched turbines weekly May-September, 2016 for mortalities, assessed eagle use via point counts year-round and the Montana Natural Heritage Program deployed acoustic bat detectors to record echolocation sequences for activity. Estimates of fatality were determined by adjusting raw carcass counts for bias using the Huso (2011) Fatality Estimator software. Bat activity and species presence were quantified through analysis of call sequences. We observed three Golden Eagles, *Aquila chrysaetos*, on counts

for a total of 3 eagle use minutes. We found carcasses of two Western Meadowlarks, *Sturnella neglecta*, 15 Hoary Bats, *Lasiurus cinereus*, and five Silver-haired Bats, *Lasionycteris noctivigans*. The mean bird fatality estimate was 14 (95% CI: 9-20) and for bats 221 (95% CI: 120-397). An estimate of raptor fatality is of interest, but since no raptor fatalities were encountered we used the Huso (2014) Evidence of Absence (EOA) software to assess likelihood of a raptor collision. We can assert with 95% credibility that no more than 3 raptors were killed at the site. Impacts to birds are low relative to other wind farms in the west. The observed bat fatality rate (5.5 bats/MW) is below the average but above the median fatality rate observed at 49 wind farms in the mid-west.

**Assessing Maternal Energetic Allocation During Lactation for the Weddell Seal Using Photogrammetric Techniques

Kaitlin R. Macdonald*, Ecology Department, Montana State University, Bozeman
Jay J. Rotella, Ecology Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman

Life history theory predicts that allocation of resources to reproduction varies across an individual's life as one's reproductive value changes with age. As individuals reach late life and residual reproductive value declines, they should increase the proportion of energy allocated to reproduction at a cost to future survival or reproduction, this is referred to as terminal investment. Characteristics of Weddell seal life history make this marine-mammal a model organism for investigating terminal investment. Previous research from this population has indicated that pups of older females exhibit a higher growth rate from birth to weaning compared to pups from mothers of prime and young ages. We offer three competing hypotheses that may explain observed increased growth rates of pups born to older mothers and hypothesize that this finding may be a result of terminal allocation. Maternal volume measurements obtained with photogrammetric techniques will be used to explore variation in maternal energetic allocation during lactation. A simple linear regression of maternal volume against maternal measured mass was used to obtain the prediction regression equation. We found a very strong relationship between measured masses and those estimated from our predictive equation (Adjusted R2:0.8958, n=31). Estimated mass loss of mothers and apparent mass conversion efficiency from mother to pup over the course of lactation will be used to assess support for competing hypotheses. Results from this study may improve our understanding of life history theory and highlight sources of variation in population vital rates.

Using GPS/Iridium Radio Collars with Geofence Technology to Monitor Management Grizzly Bears in Northwest Montana

Timothy L. Manley*, Montana Fish Wildlife and Parks, Kalispell

Grizzly bears that come into conflict with humans may be captured, fitted with a radio transmitter, and released. The Interagency Grizzly Bear Guidelines require these management bears be radio-collared and monitored monthly. Radio collars typically used are VHF and bears can only be located by ground or aerial tracking. Locating these translocated bears is challenging, unproductive, expensive, and results in few locations. Global Positioning System (GPS) technology has greatly improved the ability to monitor bears. Advancements in

technology have resulted in radio collars such as the GPS/Iridium with Geofence technology and auxiliary schedules. In 2016, we captured and radio-collared eleven grizzly bears. Ten were fitted with Telonics TGW-4577-4 Iridium collars with a CR-5 release mechanism. These collars provided 13,864 GPS locations. One bear was fitted with a Telonics VHF collar which only provided two locations. The Iridium collars had geofencing, which was a polygon created in Google Earth that included all the private land. The collar was programmed so when a bear was outside the geofence, a GPS location was acquired every six hours. When a bear was in the geofence, a GPS location was acquired every 30 minutes. This provided more locations when a bear was on private land and near residences. The Iridium platform also provided two-way communication with the collar which allowed changing GPS acquisition rates, downloading all of the data every other day, detecting mortality, monitoring battery level, and triggering the collar to release. The advantages of this new technology to monitor grizzly bears are presented.

Baseline Indices for Calling Amphibians and Western Toads across Montana

Alexis McEwan*, Montana Natural Heritage Program, Helena
Bryce A Maxell, Montana Natural Heritage Program, Helena
Lauri Hanauska-Brown, Montana Fish Wildlife and Parks, Helena
Daniel A Bachen, Montana Natural Heritage Program, Helena

Amphibian populations are undergoing global decline, and nearly one-third of the world's amphibian species are threatened. Structured surveys can use a variety of invasive and non-invasive techniques to assess the status of a species while repeatable surveys allow for long-term monitoring to identify population trends. To establish baselines for species occupancy and indices for abundance we conducted two projects to inventory amphibians during May and June of 2016. We conducted roadside calling surveys for species that advertise breeding through calls and lentic surveys at known breeding locations of the Western Toad (*Anaxyrus boreas*). Roadside surveys were broken into west and east regions based on species distributions. We detected two species at seven of the eight western transects, Pacific Tree Frog (*Pseudacris regilla*) and American Bullfrog (*Lithobates catesbeianus*). The Pacific Tree Frog was identified at 19% of the stations sampled, but at low densities. In the east, we detected five species of amphibians at 18 of the 19 transects, Boreal Chorus Frog (*P. maculate*), Northern Leopard Frog (L. pipiens), Great Plains Toad (*A. cognatus*), Woodhouse's Toad (*A. woodhousii*), and Plains Spadefoot Toad (*Spea bombifrons*). The Boreal Chorus Frogs were most commonly detected (39%) followed by Woodhouse's Toad (13%) and Plains Spadefoot (12%). Of the 76 sites we surveyed for Western Toad, 63% had evidence of breeding. These surveys can be used as primary indices for future surveys to determine trends in abundance and occupancy through time and inform state status ranks.

Better Bullets: How to Shoot Varmints Without Poisoning Scavengers

Michael McTee*, MPG Ranch, Florence, MT
Matt Young, Environmental Biogeochemistry Laboratory, University of Montana, Missoula
Andre Umansky, Environmental Biogeochemistry Laboratory, University of Montana, Missoula
Philip Ramsey, MPG Ranch, Florence, MT

Recreational shooters kill millions of varmints each year. The carcasses can contain fragments of lead that scavengers can ingest. Less toxic bullets may alleviate the problem but their performance needs to be determined. In this study, ground squirrels were shot with

.17 HMR, .22 LR, and .223 Rem rifles with expanding and non-expanding lead and non-lead bullets. We monitored whether the bullets instantly incapacitated ground squirrels and then estimated lead concentrations in each carcass using radiographs. We found lead in the majority of ground squirrel carcasses that were shot with five out of six lead bullets tested. Expanding ammunition in the .17 HMR and the .223 Rem calibers left the highest estimated concentrations of lead in ground squirrels, which had, on average, 23.6 and 91.2 mg/carcass, respectively. Within a caliber, expanding bullets did not contaminate ground squirrels more than non-expanding bullets. Non-lead bullets incapacitated ground squirrels as well as lead bullets. Recreational shooters and land managers may reduce the amount of lead available to scavengers by using non-lead bullets when shooting ground squirrels and other varmints.

Montana's IMBCR Program: Utility of Seven Years of Statewide Landbird Monitoring Data

Christian M. Meny*, Dept of Biological Sciences, Boise State University, Boise, ID
Jay D. Carlisle, Dept of Biological Sciences, Boise State University, Boise, ID
Matthew McClaren, Bird Conservancy of the Rockies, Fort Collins, CO
Rob Sparks, Bird Conservancy of the Rockies, Fort Collins, CO

The 2016 field season marks the 7th consecutive year of statewide implementation of the Integrated Monitoring in Bird Conservation Regions program (IMBCR) for monitoring bird populations in the state of Montana. Using a spatially-balanced, hierarchical study design, the IMBCR program provides density and occupancy estimates for bird species at various geographic extents (strata) across the western U.S. Based largely on agency investment, primary sampling occurs in all USFS R1 National Forests and extensive grassland/sagebrush habitats on Montana BLM lands statewide. Significant sampling also occurs in various habitats on private lands. Using these data, as well as tools available on the Rocky Mountain Avian Data Center web console, agencies and NGO partners can evaluate avian distribution and population dynamics statewide. As an effective monitoring program, the IMBCR program informs research questions, landscape-level management and conservation action. The design and current applications of the IMBCR program are summarized.

Elk Near Fossil Butte National Monument in Southwest Wyoming Migrate Early to Escape Human Disturbance

Nate L. Mikle *, USGS Northern Rocky Mountain Science Center, West Glacier, MT
Tabitha A. Graves, USGS Northern Rocky Mountain Science Center, West Glacier, MT
Edward M. Olexa, USGS, Northern Rocky Mountain Science Center, Bozeman, MT

Migration allows individuals to strike a balance between risk and reward, and use resources in the places and at times that maximize fitness. Large ungulates commonly migrate to increase access to quality forage in spring and decrease risks associated with winter weather in the fall in an effort to maintain the body condition necessary for winter survival and successful reproduction. However, foraging exists within a realm of strategies employed to maximize fitness, and so animals must take factors like safety into account when choosing to migrate. Here, we use 5 years of data from 73 female elk (*Cervus canadensis*), most of which are part of a subgroup of elk that utilize a protected area during hunting season, to identify the driving factors behind the initiation of migration from their late summer range. The onset of archery season, remotely sensed vegetation degradation, and having access to lands where hunting was prohibited (Fossil Butte National Monument) initiated autumn migration, with bad weather having a smaller effect. 67% of elk using the Monument initiated migration prior to the onset of archery hunting season (1 September), preemptively avoiding risk, while no elk from the subgroup not using the Monument left prior to archery season,

despite spending summer at higher elevations. Departure from productive summer range nearly two months before vegetation senescence afforded protection on the Monument during hunting season, but decreased access to late summer-fall forage (integrated NDVI) by 21%. Our results illustrate the complexity of managing a wide-ranging ungulate across jurisdictions with multiple missions.

**Effects of Grazing Management on Sharp-Tailed Grouse Nest Survival in Mixed Grass Prairies

Megan C. Milligan*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance B. McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Lorelle I. Berkeley, Montana Department of Fish, Wildlife, and Parks, Helena

Grazing is the predominant land use across western North America and directly affects the structure, composition, and productivity of native grasslands. Thus, grazing management has a significant impact on the quality and extent of wildlife habitat. Sharp-tailed grouse (*Tympanuchus phasianellus*) have large home ranges and utilize a wide range of habitat types, allowing them to serve as an ideal indicator species for grassland habitats. To better understand the relationship between rangeland management, habitat conditions, and nesting ecology, we monitored 50 radio-collared sharp-tailed grouse in eastern Montana to assess the effects of grazing management, local habitat, and female attributes on nest survival. In the first year of a three-year study, we monitored 73 nests, 27 of which successfully hatched at least one chick. Probability of daily nest survival was 0.96 ± 0.006 and overall nest survival during the nesting period was 0.24 ± 0.05. Variables at the home-range scale, including grazing system and grassland shape complexity, were better predictors of nest survival than variables at the nest-scale. Nest survival declined with female age, and was higher for nests located in pastures managed with season-long grazing than for pastures managed with rotation and rest-rotation grazing. However, confidence intervals of effects overlapped 0 and a null model was considered parsimonious, suggesting little to no direct effect of grazing system on nest survival during our first year of study. By evaluating the influence of different rangeland management practices on demographic rates, this project will develop specific management recommendations for the conservation of sharp-tailed grouse.

Scientific Integrity: Producing, Incorporating, and Advocating for Science in the Age of Alternative Facts

Brendan Moynahan*, Research Coordinator and Science Advisor, National Park Service, Missoula, MT
Randy Matchett, Senior Wildlife Biologist, Charles M. Russell National Wildlife Refuge, U.S. Fish and Wildlife Service, Lewistown, MT
Mike Mitchell, Unit Leader, Montana Cooperative Wildlife Research Unit, Missoula, MT 59812
Justin Gude, Wildlife Research & Technical Services Bureau Chief, Montana Department of Fish, Wildlife, and Parks, Helena, MT
Scott Mills, Associate Vice President of Research for Global Change and Sustainability, The University of Montana, Missoula, MT
Dale Becker, Wildlife Program Manager, Confederated Salish and Kootenai Tribes, Polson, MT
Janene Lichtenberg, Director, Wildlife Biology Department, Salish Kootenai College, Pablo, MT
Ryan Lutey, Executive Director, Vital Ground, Missoula, MT
Keith Aune, Bison Program Director, Wildlife Conservation Society, Bozeman, MT

Technical information – along with politics, economics, public opinion, societal values, and legal considerations – is one input into wildlife management decisions. As information consumers, decision-makers require objectivity of those who produce such information, and

should have an understanding of the inference scope and strength (and uncertainty) associated with technical information. Information producers must earn, demonstrate, and protect that reputation of objectivity. Both producers and consumers must both foster and guard a culture of integrity, such that the processes of producing and applying information are transparent and can withstand intense scrutiny. Today, rather suddenly, there is national discourse on these subjects of transparency, professional integrity, and rigorous questioning and defense of scientific information. The discussion of the role of science and scientists in informing public policy has assumed a prominent position in traditional and social media. This panel, consisting of representatives from federal, state, tribal, and non-governmental organizations will engage in this discussion with the audience.

Mule Deer Research and Management in the Bitterroot Valley, Western Montana

Rebecca Mowry*, Montana Fish Wildlife and Parks, Hamilton
Kelly Proffitt, Montana Fish Wildlife and Parks, Bozeman
Ben Jimenez, Montana Fish Wildlife and Parks, Missoula
Craig Jourdonnais, MPG Ranch, Missoula, MT

Mule deer in the Sapphire Mountains on the east side of the Bitterroot Valley exist across a variety of habitats, densities, and management strategies, including the most popular trophy buck management area in the state of Montana (Hunting District 270 in the south end of the Sapphires). As in many other western states, mule deer populations have declined over recent decades, despite relatively good fawn recruitment. Beginning in winter 2015-2016, we used ground-based darting to deploy GPS collars on 30 adult female deer in HD270 and HD204 (north end of the Sapphires) to evaluate seasonal movements and causes of mortality. These areas were chosen not only because they represent a spectrum of environmental and management conditions, but because extensive data on habitat and forage quality in this area was collected as part of preceding elk habitat research. To date, we have observed a wide variety of movement strategies, from resident deer maintaining a small home range year-round in areas of high private land ownership to migratory deer moving from summer to winter range. Causes of mortality consisted of coyote predation (n=2), human hunting (n=1), and unknown mortality (n=1) in HD204, and natural mortality (n=1) and mountain lion predation (n=2) in HD270. This is an ongoing study by which we hope to evaluate factors limiting deer populations to help inform future management.

Montana Fish, Wildlife and Parks – A Wildlife Habitat Conservation Heritage

Rick D. Northrup*, Montana Fish Wildlife and Parks, Helena

The course of wildlife habitat conservation in Montana was set in 1940, with the initial purchase of 1,000 acres, the "Judith River Game Range". This was the start of extensive investment in wildlife habitat conservation across the state. Hunting license, Pittman-Robertson Federal Aide, USDA Forest Legacy, and funds from many partners have helped to conserve and manage nearly 890,000 acres of high priority wildlife habitats across Montana. I used historical records, program database queries, interviews, and popular articles from the Montana Outdoors publication to summarize conservation highlights from over the past 80 years. Two programs have been instrumental in accomplishing perpetual conservation in recent history. Since 1987, Habitat Montana has invested over $75 million and leveraged $66 million in partner funds. Since 2001, the Forest Legacy Program has invested nearly $65 million in Montana in addition to $60 million of partner funding, specifically for forest land conservation. In total, Montana Fish, Wildlife and Parks (FWP) and partners have

invested $290 million toward wildlife conservation easements and land purchase, including $42 million of donated value by landowners. FWP currently owns 385,000 acres, managed as wildlife management areas. Wildlife habitat conservation easements total 448,000 acres, making FWP the 10th largest holder of conservation easements in the nation. Conserved habitats span coniferous forest, intermountain grasslands, riparian bottomlands, wetlands, prairie, and shrub grasslands, benefitting many species. These lands substantially overlap with mapped priority habitats, involving hunted game and species of concern. Broad public support is essential to program survival. Such support appears to hinge on various project outcomes, including conservation benefits, compatible recreation, economic benefits, managing land as a good neighbor, and tapping local producers to assist with management.

Montana Fish, Wildlife and Parks Statewide Forest Management Plan

R. Jason Parke, Montana Fish Wildlife and Parks, Helena

Montana Fish, Wildlife & Parks (FWP) is responsible for managing approximately 150,000 acres of forested land across 36 Wildlife Management Areas (WMAs). Since 2009, Montana's legislature has passed several bills prescribing forest management on these lands and requiring FWP to adopt forest management plans. Work is progressing towards developing a statewide forest management plan. FWP is proposing a forest management plan that employs a "filter" approach with emphasis on conserving biodiversity. Our premise is that implementing this approach will provide sustainable habitat conditions for the variety of species endemic to these forests.

28 Years of Upland Game Bird Habitat Enhancement in Northeast Montana

Kenneth B. Plourde*, Montana Fish Wildlife and Parks, Flaxville

In 1989 Montana's Upland Game Bird Enhancement Program (UGBEP) was authorized to develop, enhance, and conserve upland game bird habitat in Montana using funding from upland game bird license sales. A combination of high public interest, robust game bird populations, and an extensively cultivated landscape in the northeastern corner of Montana made it a natural focus area for the new program. Habitat enhancements completed under the program included establishing nesting cover, shelterbelts for winter cover, and food plots as well as implementing rest-rotation grazing systems. Over the ensuing 28 years, 431 habitat projects were completed in a five county area. Most projects were completed in cooperation with private landowners and nearly all of the habitat enhancements occurred on private lands. Many projects resulted from partnering with Farm Bill conservation programs. Good working relationships between FWP staff, landowners, and partnering agencies played a key role in the success of the program. A discussion of achievements, challenges, and lessons learned from the UGBEP in northeast Montana may provide insight for wildlife managers dealing with habitat conservation issues across the state.

**Habitat Selection, Movements, and Survival of Dispersing Juvenile Beavers in Southwest Montana

Torrey D. Ritter*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance B. McNew, Department of Animal and Range Sciences, Montana State University, Bozeman

North American Beaver (*Castor canadensis*) colonies provide a variety of benefits to stream systems by capturing and storing water and sediment, expanding riparian habitats, and increasing habitat heterogeneity. Land and wildlife managers are increasingly interested in implementing beaver restoration projects with the goal of improving stream health and landscape water storage capacity. However, most research on habitat selection by beavers does not address habitat requirements when beavers form new colonies in novel areas, as is the objective of most beaver restoration efforts. We radio-marked juvenile beavers in the upper Gallatin and Madison River drainages to investigate dispersal, survival, and settlement site selection with the goal of improving the ability of managers to identify beaver restoration sites with the highest probability of success. Following the first year of data collection, we found the dispersal rate was low (0.16 ± 0.084) and the survival rate was high (0.82 ± 0.082) among our radio-marked beavers. Out of 50 active beaver colonies discovered in the study area in 2016, only 5 were new settlement sites. Newly-settled sites generally had a higher proportion of willow-dominated habitat types than unsettled sites while all other measured habitat variables were similar between settled and unsettled sites. Our observations indicate old beaver structures are frequently used by dispersing beavers when establishing a new colony. We assert that examination of local beaver densities and the spatial distribution of active colonies are essential components of a successful beaver restoration project, and should precede evaluations of habitat quality at potential restoration sites.

**Responses of Songbird Population to Cattle Grazing Regimes in Sagebrush-Steppe of Eastern Montana

Kayla Ruth*, College of Forestry and Conservation, University of Montana, Missoula
Lorelle Berkeley, Montana Fish Wildlife and Parks, Helena
Victoria J. Dreitz, College of Forestry and Conservation, University of Montana, Missoula

Sagebrush-steppe ecosystems in western US are characterized as a landscape mix of sagebrush shrubs and grass vegetation. A large portion of sagebrush-steppe across the west is used for grazing of domestic livestock, primarily cattle. We compared songbird communities over four breeding seasons in eastern Montana between two grazing systems: rest-rotation and traditional grazing. Rest-rotation involves grazing areas (or pastures) at different annual seasons across years allowing pastures to be rested between the same consecutive seasons. Traditional grazing is defined as grazing a pasture repeatedly at the same annual season each year. Recently, rest-rotation has been used as a conservation management tool by the Natural Resource Conservation Service's (NRCS) Sage Grouse Initiative (SGI) program. The goal is to improve habitat for greater sage grouse (*Centrocercus urophasianus*) through livestock grazing. We explore the effects of rest-rotation compared to traditional grazing on songbird population breeding demographics: adult abundance, nest densities and nest success. Abundance is a metric often used to assess conservation actions given the ease in collecting data to estimate this parameter. However, information on how the conservation actions influences the life histories, such as nest density and nest success, that determine abundance are lacking. Our goal is to understand the relationship between patterns in abundance, nest density, and nest success and how rest-rotation grazing influences those patterns. This knowledge will provide information on how to best manage for multiple songbird species in sagebrush-steppe by determining how conservation management tool affects individual songbird populations.

Resource Selection, Predation Risk, and Underestimates of Refuge Habitat for an Alpine Obligate

Wesley M. Sarmento* Blackfeet Fish and Wildlife, Browning, MT
Joel Berger, Colorado State University, Fort Collins

Understanding relationships between animals and their habitat is a central goal in ecology with important implications for conservation. Misidentified habitat requirements, however, can have serious repercussions because land protections or reintroductions might occur in areas of less than optimal habitat. Studies of resource selection have greatly facilitated an understanding of relationships but suffer because rarely used, but vital habitat features may be insufficiently described. A critical element for many prey species is escape terrain or some form of refuge. Mountain goats (*Oreamnos americanus*) are a species well known for their use of cliffs to escape predation, but a survey of the literature reveals at least twelve different approximations of goat escape terrain. Here, we sought to 1) optimize mountain goat escape terrain estimates, and 2) highlight the assumption that the time an animal spends in an area is proportional to importance. We experimentally exposed mountain goats to grizzly bear (predation risk) and ungulate (control) imitations and recorded subsequent escape locations in Glacier National Park, Montana, USA. Through a used-unused resource selection function we tested 21 landscape variables for explaining goat escape terrain. We found that distance to slopes greater then 60o best explained where mountain goats fled. Additionally, we identified the need to incorporate behavior and predator interactions into resource selection studies. With 27 failed mountain goats reintroductions these results have consequences on habitat characterization and considerations for species restoration. Managers should consider the availability of escape habitat when protecting land or reintroducing prey species.

Patterns and Spatial Prediction of Livestock Predation by Grizzly Bears on the Blackfeet Reservation

Wesley M. Sarmento* Blackfeet Fish and Wildlife, Browning, MT
Dan Carney, Blackfeet Fish and Wildlife, Browning, MT

Human caused mortality is a primary limiting factor in carnivore conservation globally. A large proportion of predator persecution is the result of retaliation due to lost livestock. If carnivore conservation is to succeed then the economic burden on livestock producers needs to be ameliorated. Proactively preventing livestock depredation is perhaps the most effective method to solve conflicts compared to reactively relocating problem animals or reimbursing people for losses. Large carnivores, however, range across wide areas while management dollars are limited and thus where to implement conflict prevention measures is a matter of triage. To prioritize conflict prevention efforts we examined 23 years of data on livestock depredation by grizzly bears (*Ursus arctos*) across the Blackfeet Indian Reservation. Since 1993 livestock loss by grizzlies has increased an average of 6% per year and depredations were positively associated with warmer weather. Additionally, we forecasted spatial risk by estimating the relative probability of livestock loss across the reservation. Using logistic regression models we tested remotely sensed landscape variables to understand how habitat features influence the risk of depredation by bears. We found that locations closer to trees had the highest chance of livestock loss. Furthermore, places closer to perennial and seasonal water also had increased risk. Topography also influenced depredation probability with lower elevations and gentler slopes having increased risk. In all, our results will provide 1) managers a clear path in prioritizing areas to receive conflict prevention resources, and 2) livestock growers a knowledge of how to distribute animals to reduce risk.

Genetic Variation of Garter Snakes Across Western Montana

Matthew Schertz*, MPG Ranch, Florence, MT
Stephen Spear, The Wilds, Cumberland OH
Denim Jochimsen, University of Idaho, Moscow

This study addresses the variability in garter snakes across Western Montana. Some common garter snakes in the region exhibit characteristics of the valley garter (*sirtalis fitchi*), a subspecies typically found west of the continental divide. Other specimens exhibit characteristics of the red-sided garter snake (*sirtalis parietalis*), a subspecies found east of the continental divide. Wandering garter snakes (*elegans vagrans*) across Western Montana also exhibit a great deal of variability. Using tissue samples from 108 common garters, 185 wandering garters and 3 melanistic snakes across Western Montana, we explore the effect of distance, topography and land cover on the genetic similarity between members of both species. In addition, we examine whether genetic differences account for phenotypic differences amongst species and whether microsatellite sequences indicate geographic isolation, assortative mating or inbreeding among garter snakes.

Common Themes in Recent Human Fatalities Due to Grizzly Bear Attacks

Christopher Servheen*, Dept of Ecosystem and Conservation Science, University of Montana, Missoula

There have been 8 fatal grizzly bear attacks on humans in the lower 48 states since 2001. Of these, 6 occurred in the Yellowstone Ecosystem, and 2 occurred in the Northern Continental Divide Ecosystem. An additional encounter occurred in the Cabinet/Yaak ecosystem where a hunter shot and wounded a grizzly bear and then entered thick brush in pursuit of the wounded bear. The bear then attacked him and his hunting partner accidentally shot and killed him while trying to shoot the bear. Of the 8 fatal attacks, 4 occurred in National Forests, 3 in Yellowstone Park, and 1 on Montana state game range lands. Human behaviors at the time of the attacks involved hunting, camping at night, hiking, and mountain biking. Seven of the eight attacks occurred during daylight. Five of the fatalities involved lone individuals and 4 of these were lone hikers. Bear spray was not carried or used by any of the people killed in these attacks. Consistent messaging by management agencies about how to be safe in bear country has not been successful in convincing the public to adopt safety practices. Further efforts are necessary to educate users in grizzly habitat of the risks involved with certain behaviors and the cost of ignoring agency safety messages. The likelihood of fatal encounters could be significantly reduced by the adoption of common safety practices such as not hiking or hunting alone, not running when encountering a bear, the use of bear spray, and understanding the increased danger involved when surprising a bear due to fast travel in grizzly county by trail running or mountain biking.

The Status of the Grizzly Bear in the Northern Rockies: Progress Toward Delisting?

Christopher Servheen*, Dept of Ecosystem and Conservation Science, University of Montana, Missoula

Grizzly bears in the Yellowstone Ecosystem have met recovery goals, are recovered, and should be delisted. Successful delisting under requirements of the Endangered Species Act requires meeting recovery goals and requires that adequate regulatory mechanisms be in place post-delisting so that the species will remain recovered. Acceptable mortality management

including some level of sport hunting could be possible if science-based mortality limits to stabilize the population are carefully applied within the core management area post-delisting. Unfortunately, some agency administrators have removed necessary regulatory details about mortality management and wish to limit to limit the time period for application of the regulatory mechanisms that would be used to demonstrate recovery. The same administrators have pushed for managed population decline inside core recovery area after delisting. Managed population decline in the core recovery area is scientifically indefensible for a species like the grizzly with such a low reproductive rate. State administrators also removed any reference in the post-delisting management plan to the important fact that grizzly bears are a conservation-reliant species (Scott et al. 2010; Goble et al. 2012) and will require careful management in perpetuity. Ideologically based erosion of science and necessary regulatory mechanisms puts successful delisting at risk. Such an approach does not serve: 1) the needs of the public who have been partners with the agencies in the achievement of recovery and who desire successful delisting to obtain increased management flexibility outside core areas; or 2) the conservation of grizzly bears who need public support to remain recovered.

Birds, Herps, and Small Mammals! Oh, My! Help FWP Find Rare and Elusive Species (Poster and Oral Presentation)

Brandi Skone*, Montana Fish Wildlife and Parks, Miles City
Heather Harris*, Montana Fish Wildlife and Parks, Glasgow
Lauri Hanauska-Brown, Montana Fish Wildlife and Parks, Helena
Allison Begley, Montana Fish Wildlife and Parks, Helena
Kristi DuBois, Montana Fish Wildlife and Parks, Missoula
Claire Gower, Montana Fish Wildlife and Parks, Bozeman
Chris Hammond, Montana Fish Wildlife and Parks, Kalispell
Megan O'Reilly, Montana Fish Wildlife and Parks, Billings
Kristina Smucker, Montana Fish Wildlife and Parks, Great Falls

In 2014, Montana Fish, Wildlife & Parks (MFWP) expanded their Nongame Program to include a Wildlife Biologist specializing in nongame species work in every region. Although each region has different priorities, the goals within the Nongame Program are universal: (1) Keep common species common, (2) Reverse population declines for species of concern, and (3) Foster awareness and enhance public knowledge and appreciation of nongame species. Our efforts are guided by the State Wildlife Action Plan (SWAP) which prioritizes work on habitats and species of greatest conservation need. These efforts include anything from developing habitat conservation projects to surveying single species. Within the SWAP there are a number of species considered Species of Greatest Inventory Need because they lack sufficient data to determine their status. Often these species are rare, elusive, or difficult to observe. Consequently, we seek the help of others to provide incidental observations in addition to our structured survey efforts. Some of our high priority species include: (1) black rosy-finch, a small high-alpine songbird, (2) greater short-horned lizard, a cryptic reptile dependent on sparse habitat, (3) black-tailed jack rabbit, a lesser-known lagomorph found in open country habitat, and (4) black swift, the largest of the swift species, nesting secretively in shallow caves and behind waterfalls. People interested in assisting with surveys should contact the appropriate FWP nongame lead. By working together, we can provide managers and regulatory agencies with vital information to make well-informed decisions about our valued resources in Montana.

**The Effect of Climate-Driven Phenological Shifts on Plant-Pollinator Interactions and Plant and Pollinator Reproductive Success

Anthony H. Slominski*, Ecology Department, Montana State University, Bozeman
Laura A. Burkle, Ecology Department, Montana State University, Bozeman

Plants and pollinators are shifting their annual bloom periods and emergence dates (i.e., phenologies) in response to ongoing climate-warming. However, the magnitude of phenological shifts can be species-specific, causing concern that unequal responses will disrupted plant-pollinator interactions (i.e., phenological mismatches) and create novel community composition throughout the growing season. The effects of phenological mismatches on plants and pollinators remains unknown, preventing conservation strategies that pinpoint the most vulnerable species. The goal of this study was to investigate the effects of phenological shifts on plants and bees by manipulating plant-bee community composition within mesh-sided enclosures (mesocosms). Plant-bee communities were assembled following a factorial design based on phenologies (i.e., spring vs. summer blooming plants and spring vs. summer emerging bees), allowing a comparison of plant-bee interactions and reproductive success within 'phenologically matched' communities (e.g., spring blooming plants with spring emerging bees) and 'phenologically mismatched' communities (e.g., spring blooming plants with summer emerging bees). Preliminary results suggest that interaction frequency was similar between 'mismatched' and 'matched' communities, implying that plants and bees can compensate for interactions disrupted by phenological mismatches. Currently, I am processing the reproductive data from both plants (i.e., seed set) and bees (i.e, total offspring) to determine if interaction frequency is indicative of reproductive success.

Wind Energy Development in Montana: Guidance for Effective Agency Involvement to Minimize Wildlife Impacts

Kristina Smucker*, Montana Fish Wildlife and Parks, Great Falls
Kyla Maki*, Department of Environmental Quality, Helena, MT
Renee Lemon, Montana Fish Wildlife and Parks, Helena
Kimberly Linnell, Montana Fish Wildlife and Parks, Great Falls

Montana is one of the top five states for wind energy potential but ranks 19th for installed wind energy, with 691 megawatts of capacity built. Nationwide, wind energy development is on track to provide 20% of the country's electricity by 2030 and wind turbine technician is the fastest growing job in the nation. Wildlife managers in Montana will see more wind development projects come across their desks but may have limited experience with review. We present an overview of existing and potential wind farms in Montana and the typical process for project permitting and development. Wind has great potential as a source for green energy but improperly sited wind projects pose threats to wildlife including potential risk of bird and bat collisions; displacement of nesting raptors, songbirds, and prairie grouse at leks; and habitat fragmentation. In 2015, Montana Fish, Wildlife and Parks began wildlife monitoring at a wind farm near Geyser, giving the department direct experience designing and implementing fatality monitoring. The key to wildlife friendly wind development is early consultation with state and federal agencies and open discussion of survey results. To assist developers, USFWS has produced the Wind Energy Guidelines (WEG) and Eagle Conservation Plan Guidance (ECP). These are voluntary guidelines, but both aim to walk developers through the process of identifying, avoiding, and minimizing impacts to wildlife and key habitats. To assist biologists, we will summarize impacts to wildlife, give a short-course on the WEG and ECP, identify opportunities for agency involvement at each stage of development and offer a framework for effective consultations.

Future Upland Gamebird Extension Programs in Montana: Assessing the Needs of County Agents

Richard S. Sojda*, Gianforte School of Computing, Montana State University, Bozeman

In cooperation with Pheasants Forever and Montana State University, I surveyed all 48 county extension agents in Montana who have roles in addressing wildlife and natural resource issues. Twenty-five replies were received, which was a response rate of 52%. Agents expressed considerable interest by landowners and producers in various aspects of upland gamebird management. Sixty-eight percent of agents perceived that the current interest in gamebirds by ranchers, agricultural producers, and other landowners is either medium or high, and that interest will remain stable through 2021. Information on food plots was expressed as being the greatest need, with recommendations for plantings to improve game bird habitat being foremost. Nearly all agents (88%) indicated that producers have considerable interest in cover crops in small grain, including the implications for upland gamebirds. Based on responses received, I recommend that demonstration days and field tours will be the most useful tools to incorporate in future extension program development. Agents also expressed a need for making wildlife expertise available via email. Seventy-nine percent of agents placed substantial priority on in-service training for themselves in gamebird ecology and management, so this is also a valuable future program. I believe that county extension agents can have a significant effect on providing guidance to the future of upland gamebird management by agricultural producers. In so doing, gamebird habitat and numbers might be positively affected across a large portion of Montana.

The Eagle has Landed: Winter Eagle Research Takes Flight in the Bitterroot Valley

Kate Stone* MPG Ranch, Florence, MT
Adam Shreading* Raptor View Research Institute, Missoula, MT

We began capturing Golden Eagles on the MPG Ranch in the Bitterroot Valley in 2011. Though we began with the intent of using satellite transmitters to learn about the habitat use and migration paths of adult, overwintering Golden Eagles, our research has evolved to encompass placing auxiliary markers on Golden and Bald Eagles of all ages. We also test eagles for environmental contaminants. So far we have captured and marked more than 75 Golden and 20 Bald Eagles. Due to these markers, we've amassed an impressive archive of eagle re-sightings in the Bitterroot Valley and other locations, including Washington and British Columbia. We've also learned that the majority of eagles captured show signs of lead exposure, likely from the ingestion of lead ammunition fragments. This year, we expanded efforts to study wintering eagles throughout the Bitterroot Valley. We've joined forces with Bitterroot Audubon and private landowners to set out carcass and camera stations on private lands throughout the valley. These efforts should increase the likelihood of re-encountering our marked eagles, demonstrate the value of private lands to eagles and other scavengers, and engage people from a variety of backgrounds with our research. We will share preliminary results from this collaboration, including impressive camera “captures” of Bald Eagles, Golden Eagles, and other scavengers. We will also share information about the public platform we are using to crowd-source image identification; this platform is available for other camera-trapping projects in Montana.

Montana Peregrine Falcon Population Survey: 2016

Jay S. Sumner*, Montana Peregrine Institute, Arlee

The release of 617 captive-bred young during the 1980's and 1990's sparked the recovery of the Peregrine Falcon (*Falco peregrinus*) in Montana. By 1994, a mix of state, federal, and private biologists (Montana Peregrine Falcon Working Group) documented 13 known active Peregrine Falcon territories. For the following four years, the number of known territories averaged about 16, but then intensive survey efforts in 1999 documented a total of 28 territories. The number of active Peregrine Falcon territories discovered in Montana has increased yearly. Montana had a record number of 108 active Peregrine Falcon territories recorded during the 2012 field season. By the end of the 2016 field season, we have recorded 207 active Peregrine Falcon territories. Annual survey objectives include the establishment of a citizens group (Project Peregrine Watch) to monitor individual Peregrine territories throughout the state, determine status and trends of Montana's Peregrine Falcon population, study all known historic Peregrine Falcon eyries, record occupancy and productivity at all active territories, locate new Peregrine Falcon territories, seek confirm and consolidate information from all public and private sources, record activity and locations of neighboring cliff-nesting raptors (Prairie Falcon (*Falco mexicanus*), Golden Eagle (*Aquila chrysaetos*), and the Red-tailed Hawk (*Buteo jamaicensis*), and develop a long-term and cost-effective monitoring program for determining annual status and population trends of the State's Peregrine Falcon population.

**Response of Amphibian and Invertebrate Communities to Wetland Mitigation in the Greater Yellowstone Ecosystem

Leah K. Swartz*, Wildlife Biology Program, University of Montana, Missoula
Blake R. Hossack, U.S. Geological Survey, Aldo Leopold Wilderness Research Institute, Missoula, MT
Winsor H. Lowe, Division of Biological Sciences, University of Montana, Missoula

In the United States, a "no net loss" of wetlands policy mandates that when wetland impacts cannot be avoided, they must be mitigated by creating or restoring wetlands of equal or greater area. A primary goal of these projects is often habitat replacement, but success is generally evaluated only through presence of wetland-associated vegetation and physical characteristics, which may not be good surrogates for wetland function. Because amphibians and aquatic macroinvertebrates integrate processes at multiple levels and are sensitive to conditions in both the aquatic and surrounding terrestrial environment, evaluating their response to wetland mitigation may be more meaningful. The Wyoming Department of Transportation recently (2008-2013) constructed and restored 38 wetlands in Teton County, WY to mitigate for loss of wetland area caused by a road reconstruction project. Our objectives were to assess differences in species richness and community composition of amphibian and aquatic macroinvertebrate communities among ten constructed, seven impacted and ten reference wetlands. Preliminary results suggest that amphibians and invertebrates have quickly colonized created wetlands, leading to similar species richness among wetland types, but that community composition remains distinct even several years after wetland construction. These results suggest that wetland creation may be an important tool, but that the life histories of target species should be accounted for in the design phase to maximize the probability of native amphibian and invertebrate colonization and persistence.

Growing the Relevance of Wildlife Management in Uncertain Times

Michael J. Thompson*, Montana Fish Wildlife and Parks, Missoula

Political unrest in the United States requires wildlife managers in Montana to consider the shifting context within which citizens engage wildlife and wildlife agencies. The state and national elections of 2016 gave voice to concerns about losses of trust, safety and security. The public seeks or is bracing for change, arguably and in part for the sake of change, with consequences that have yet to unfold. Historically, the wildlife profession has been seen by some as an obstacle to change. In today's social environment, the wildlife profession risks censure, with political consequences, if seen as a distraction from overarching public concerns. Conversely, the opportunity exists to redirect its focus on leadership toward a desired future. To lead, the wildlife profession in Montana must connect with the issues of trust, safety and security that seem elemental on the minds of Montanans today. Thus, the wildlife profession would do well to help reinforce the societal underpinnings upon which amenity values can be conserved. For example, now is the time for the wildlife profession in Montana to lead openly in addressing climate change and the advance of invasive species. It could be seen prescribing the innovative use of renewable resources to meet social and economic, as well as environmental needs. The wildlife profession in Montana could set a more obvious and intentional example for workforce diversity and human respect. Montana's model of habitat conservation could more visibly include a vision toward a future when wildlife and people are better integrated on the landscape.

Contact Patterns Among Bighorn Sheep In and Around Glacier National Park

Marie I. Tosa*, USGS Northern Rocky Mountain Science Center, West Glacier, MT
Tabitha A. Graves, USGS Northern Rocky Mountain Science Center, West Glacier, MT
Kim A. Keating, USGS Northern Rocky Mountain Science Center, Bozeman, MT
Mark J. Biel, Glacier National Park, West Glacier, MT
Daniel W. Carney, Blackfeet Fish and Wildlife Department, Browning, MT
Barb Johnston, Waterton Lakes National Park, Waterton Park, AB

Identifying patterns of direct contacts among individual animals is important to understanding infectious disease transmission. Social behavior can be influenced by both intrinsic and extrinsic variables and can be explored at 3 levels: social network structure, dyad structure, and contact structure. We investigated drivers of contact structure using GPS locations of 87 male and female bighorn sheep (*Ovis canadensis*) in and around Glacier National Park in Montana, USA. Focusing on contacts between sheep moving separately, we examined relationships between contact locations and movement variables, land cover, distances to various resources, and variables known to influence survival using a resource selection function. Used and available points were defined as simultaneous locations within 25 m (the contact-used) and 13 km (largest step length- available) of another collared bighorn sheep, thus results of this analysis describe the strengths of these variables relative to habitat use. Data were analyzed separately according to dyad type (male-male, female-female, male-female). Most contacts occurred in March for male-male and female-female dyads and in November, December, and January for male-female dyads. For male-male dyads, contacts occurred more than expected given habitat use in conifer land cover and locations farther from perennial water sources, high NDVI, little canopy cover, and low and high solar radiation index. For female-female dyads, contacts occurred less than expected given habitat use in

grass and barren land cover and locations with intermediate terrain ruggedness, high NDVI, and low and high snow water equivalent. For male-female dyads, contacts occurred most during the night, least during the day, and at locations with intermediate elevation and farther from escape terrain. Together, these results suggest that more specific conditions apply to contact locations than general locations and that we can predict locations where contacts are most likely to occur, which may be useful for disease management.

Monitoring Hoary Marmots: Matching Objectives to Available Effort

Ben Y. Turnock*, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman
John Vore, Montana Fish, Wildlife and Parks, Helena
Chris Hammond, Montana Fish, Wildlife and Parks, Kalispell

Monitoring provides information necessary for managers to make informed decisions related to the status of populations. However, collecting sufficient data to reliably detect trends in abundance over a large area is costly in time and resources. Instead, detecting changes in distribution may be a more feasible goal, while still providing useful information. Hoary marmots are alpine obligates, patchily distributed throughout the mountains of western North America. This species requires deep winter snowpack to survive during winter and populations at the edges of their distribution are most likely to be vulnerable to changes in climate. We sought to design a monitoring plan that could identify changes in distribution of hoary marmot populations. We used occupancy methods to create a predictive habitat map for hoary marmots in western Montana. We evaluated designs that could be implemented by existing staff or with 2 dedicated technicians and assessed tradeoffs in the number of sites and surveys needed to detect a change in distribution. We also evaluated the effort needed to sample throughout Montana or within selected mountain ranges. Based on our analyses, managers will need to complete surveys at ≥65 sites at least twice a season and without dedicated technicians, the area sampled will be limited. Hoary marmots likely will be negatively impacted by climate change, especially in isolated mountain ranges at the southern extent of their distribution. Assessing the magnitude of these changes will be impossible without sufficient data, highlighting the importance of identifying monitoring objectives before data collection begins.

Western States Wolverine Conservation Project Baseline Survey

Alex Welander*, representing the Western States Wolverine Working Group which consists of numerous individuals within Montana Fish Wildlife and Parks, Wyoming Game and Fish, Idaho Fish and Game, Washington Fish and Wildlife, Colorado Parks and Wildlife, United States Fish and Wildlife Service, United States Forest Service, National Park Service, Confederated Salish and Kootenai Tribes; University of Montana, Montana State University, Colorado State University, and Woodland Park Zoo

The wolverine is a naturally uncommon species whose conservation and management requires collaboration across a large geography. Conservation priorities for wolverines in the western U.S. have been identified as 1) Connectivity, 2) Restorations, and 3) Monitoring. The Western States Wolverine Working Group is a collaborative effort among state, federal, tribal, university, and private organizations that are actively working on these priorities. One element of the conservation program is baseline survey for wolverine occupancy across the 4-states where the species currently occurs – Montana, Wyoming, Idaho, and Washington. The survey uses a grid of 15 x 15 km cells. All cells >50% modelled wolverine habitat were

considered for sampling, and a GRTS sample of 180 cells was selected to be surveyed using a standard protocol across the 4-state area during winter 2016-17. A single camera/DNA station was established during November 2016 in each cell and will be run through April 2017. To date, stations in all states are successfully detecting wolverines and other species. This effort will provide the first estimate of wolverine distribution across the species range in the lower 48 and an estimate of occupancy. It will also allow investigations into a variety of genetic-based questions at the population scale, including identification of current and future areas of importance for connectivity. The survey is designed so that it can be repeated as a monitoring program and can determine changes in wolverine status (stable, increasing, or decreasing distribution via occupancy), and genetic composition over time. Results will also be used to identify potential population restoration areas if there are large areas with suitable habitat that have not yet been recolonized after historical lows.

**Livestock Depredation by Grizzly Bears on Forest Service Grazing Allotments in the Greater Yellowstone Ecosystem

Smith L. Wells*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance B. McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Daniel B. Tyers, USFS Northern Rocky Mountain Science Center, Bozeman
Frank T. van Manen, USGS Northern Rocky Mountain Science Center, Bozeman, MT
Daniel J. Thompson, Wyoming Game and Fish Department, Lander

Grizzly bear population growth and range expansion over the last several decades in the Greater Yellowstone Ecosystem (GYE) has led to increased human-bear conflicts, including livestock depredation. In 2015, we began a study to evaluate spatio-temporal relationships between livestock grazing, grizzly bear habitat characteristics, and livestock depredations by grizzly bears on public lands in the GYE during 1992–2014. In collaboration with the U.S. Forest Service (USFS), Interagency Grizzly Bear Study Team, and National Park Service, we have obtained 23 years of grazing allotment attributes for 316 USFS and Grand Teton National Park grazing allotments including: livestock stocking information, grizzly bear habitat characteristics, grizzly bear density and distribution, and livestock depredation counts. Overall counts of livestock depredation events, total livestock killed, and the number of allotments experiencing depredations increased from 1992 to 2014, concurrent with range expansion and increasing grizzly bear densities. Annual depredation events per allotment differed by livestock class, where allotments stocked with cow-calf pairs and sheep experienced the majority of depredations. Livestock depredation counts will be modeled with livestock stocking data and grizzly bear habitat variables to better understand which attributes of grazing allotments had the greatest association with the number of depredations over the study period. We will evaluate habitat attributes at two spatial scales, representing daily and annual grizzly bear activity areas. Our results will enhance adaptive approaches to conserve grizzly bears, while also maintaining the economic viability of livestock operations.

**Effects of Supplementation Strategy and Dormant Season Grazing on Cattle Use of Mixed-Grass Prairie Habitats

Sam A. Wyffels*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance B. McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Janice G.P. Bowman, Department of Animal and Range Sciences, Montana State University, Bozeman
Mark K. Petersen, USDA - Agricultural Research Service, Fort Keogh Livestock & Range Research Laboratory, Miles City, MT

Dormant season grazing reduces reliance on harvested feeds, but typically requires protein supplementation to be successful. However, information relating supplementation strategies to individual resource utilization on dormant forage is lacking. Thus, the intent of this research is to examine cattle resource utilization, residual cover of vegetation and utilization on rangelands grazed during the dormant season under two supplementation strategies. Thirty transects were randomly located within each pasture for measuring vegetation composition, production, canopy cover and visual obstruction readings (VOR) pre and post grazing. Grazing locations were monitored for seven individuals within each treatment with Lotek GPS collars containing head position sensors that record daily space use. Resource utilization effect size was variable by treatment and time period. Vegetation response to treatment was similar for both cake and protein treatments across time periods (44.2 ± 4.8% vs 41.7 ± 4.5%, 36.7 ± 4.8% vs 30.7 ± 4.3%, 10.4 ± 3.1% vs 16.5 ± 3.5%). VOR was affected by supplementation treatment during time period 1, such that protein treatment significantly decreased VOR in comparison to the Cake treatment (36.6 ± 5.6% vs 15.7 ± 3.6%). Herbaceous and ground cover effects were similar across both supplementation treatments during time periods 1 and 3, while time period 2, cake supplementation had greater percent decrease of litter cover than the protein treatment (28.2 ± 4.4% vs 10.4 ± 2.9%). This research addresses comprehensive agro-ecosystem responses of dormant season grazing while providing multidimensional insight to stakeholders concerning grazing behavior and the ecological impacts on Montana rangelands.

**Survival and Reproduction of Wild Turkeys in the Northern Black Hills of South Dakota

Michael J. Yarnall*, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman
Chad P. Lehman, South Dakota Department of Game, Fish, and Parks, Custer

In South Dakota, wild turkeys are a high-interest species for both consumptive and non-consumptive uses. Harvest records indicate that the population segment residing in the northern Black Hills may be declining. Although data on hen survival, nesting survival, and early poult survival were collected for the southern Black Hills in the early 2000s, there is currently a paucity of demographic data for the northern Black Hills. We seek to inform wild turkey management by characterizing demography specifically for the northern Black Hills. We radio-tracked 80 turkey hens (40 adults/40 juveniles) in 2016 to estimate rates of hen survival, nesting, nesting success, and early poult survival; this two-year study will continue in 2017. Based on preliminary data, rates of nesting by adult hens are lower in the northern Black Hills than the southern Black Hills (77.5% vs. 98%), as are rates of renesting by adult hens (33% vs. 75%). We are in the process of estimating hen survival, but preliminary results indicate that annual survival is approximately 50%. Poult survival to 4 weeks is comparable in the northern and southern Black Hills, but lower than in other portions of the range of Merriam's wild turkey. Although the northern and southern Black Hills are in close

proximity, the substantial climatic differences likely explain the reduced productivity of the turkey population in the northern Black Hills. Limiting fall harvest of wild turkey hens in the northern Black Hills may be required to sustainably manage this important game species.

Wolverine Reproductive Den Habitat in Glacier National Park, Montana

Richard E. Yates*, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT
Jeffrey P. Copeland, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT
John R. Squires, USDA Forest Service, Rocky Mountain Research Station, Missoula, MT

Wolverine reproductive dens occur in habitat not easily accessible to humans during the denning period (Feb – May) and can be challenging to find. As such, few den sites have been precisely described. From 2003 – 2007 we located and documented 14 natal and maternal dens of 3 reproductive female wolverine in Glacier National Park. Two females were known to have produced young in multiple years, using different den sites each year. Reproductive dens occurred at an average elevation of 1890m (range: 1805-1999m), on 9° slopes (range: 5-22°), within a variable range of aspects ($\bar{X}$=263°), and with an average snow depth of 2.6m (range: 2.4-3.4m). Den structures included downed trees, large boulders, and rock caves associated with alpine cirques, ridges, and cliff bands at, or below, existing tree line. Distance to occupied human development averaged 6.4km, and distance between denning areas of the same female in different years averaged 5.8 km. Various climate change models predict less persistent snowpack in many areas of the conterminous United States, with a resultant potential for increased isolation of island populations of wolverines.

Poster Abstracts

**Analysis of Spiny Softshell Turtle Distribution and Abundance in Four Rivers Systems in Eastern Montana (Poster)

Gabriel Aponte*, Rocky Mountain College, Billings, MT
Andrhea Massey, Rocky Mountain College, Billings, MT
Kayhan Ostovar, Rocky Mountain College, Billings, MT

The spiny softshell turtle (*Apalone spinifera*) is designated as a species of concern in the state of Montana due to a lack of knowledge regarding their conservation status, loss of habitat connectivity and anthropogenic changes in hydrology. Information on population abundance, and basic population structure for these turtle species is necessary to better understand how climatic changes, human responses to these changes, and other disturbances influence this neglected faunal component of freshwater ecosystems. To examine differences in subpopulations exposed to different environmental factors, spiny softshell turtles were studied in four river systems in south eastern Montana. Over two years a total of 328 spiny softshell turtles (283 females, 41 males and four juveniles) were captured and tagged in the Bighorn, Clarks Fork, Musselshell and Yellowstone Rivers. The proportion of males to females across all four rivers was 86.28% females and 12.5% males. Based on a method adapted from the von Bertalanffy growth model by Plummer and Mills (2015), the length of the female spiny softshell turtles were correlated to known ages from other studies and broken into four age cohorts (juvenile, subadult, reproductive adult, mature adult). Numbers of turtles in each cohort were found to be significantly different between the four rivers p <

0.00001. The Musselshell and Yellowstone Rivers had a more even distribution of age classes with the Musselshell having notably less mature adult turtles. Differences in hydrology, such as temperature, and the timing and magnitude of spring pulse flows on these four rivers may explain the observed spiny softshell turtle demographic structures.

Acoustic Assessment of Year-round Bat Activity and Distribution in Montana and Surrounding Areas (Poster)

Daniel Bachen*, Montana Natural Heritage Program, Helena
Braden Burkholder, Montana Natural Heritage Program, Helena
Alexis McEwan, Montana Natural Heritage Program, Helena
Bryce Maxell, Montana Natural Heritage Program, Helena

Montana's bat species face an array of conservation issues including wind energy development and disease. A collaborative project between state and federal agencies was initiated in 2011 to collect baseline data prior to the arrival of White-nose Syndrome and help inform surveillance and future mitigation strategies. In the last 6 years, we deployed a network of Song Meter ultrasonic acoustic detector/recorder stations at 76 sites across the region for an average of 1.8 years per station. Each detector recorded nightly bat passes across all seasons. To date 9.5 million sound files have been recorded. Using automated scrubbing and identification software we identified call sequences and generated initial species identifications, then hand confirmed species presence by month at each site. Over 54,000 bat passes have been reviewed by hand and used to track activity of all species at each site. To date we have 2,770 new records of monthly species presence, regular winter activity of 3 resident species, and year-round presence of 1 species previously considered migratory. Through integrating National Oceanographic and Atmospheric Association weather station with our call data, we have found positive correlations in activity with temperature and barometric pressure, and negative correlations with wind speed. Our experiences with these data highlight the importance of: (1) maintaining common settings across recording devices and consistent processing standards; (2) maintaining publicly available call libraries that can be reanalyzed using the latest software and made available to software developers; and (3) making standards used for species determinations available for peer review.

Historic Distribution and Abundance of Bison in the Rocky Mountains of the United States (Poster)

James A. Bailey*, Belgrade, MT

Scant public awareness of the early distribution and abundance of bison (Bison bison) in the Rocky Mountains of the United States inhibits discussion of possible restoration of wild bison. A review of written evidence, largely from 1805-1845, indicates bison were widely distributed in intermountain valleys, with a major regional concentration spanning parts of Idaho, Montana, and Wyoming. However, several interacting factors caused large spatial and temporal variation in bison abundance. Native American predation was likely a major influence on bison distribution and abundance during and shortly before 1805-1845. The area where bison were observed by early explorers underestimates the area where restoring productive herds of wild bison is possible.

**Confronting the Challenge of Whale Detection from Large Vessels (Poster)

Jennifer E. Helm*, Wildlife Biology Program, University of Montana, Missoula
Paul M. Lukacs, Wildlife Biology Program, University of Montana, Missoula
Sara H. Williams, Wildlife Biology Program, University of Montana, Missoula
Scott M. Gende, Glacier Bay National Park & Preserve, National Park Service, Juneau, AK

As a result of a moratorium on commercial whaling, most populations of large whales are increasing across the globe. However, concurrent growth in shipping means that lethal ship-whale collisions constitute a significant threat to whale conservation efforts. This study investigates the ability of ship operators to detect and avoid whales by quantifying the predictability of whale surfacing behaviors, which are the cues used to determine whale presence. Whale avoidance is challenging because whales spend most of their time underwater and thus unavailable to be detected (the "availability process"), but must be detected at sufficiently large distances (the "detection process") to enact an effective avoidance maneuver. We quantified one of the main characteristics of whale behavior that governs detectability – time breaking the surface – to create a novel model of whale surfacing patterns around ships while accounting for the detection process. We then estimated the frequency with which cues go undetected (i.e. whales break the surface but ship operators are unaware of them), as well as the frequency with which whales are present but unavailable for detection (i.e. below the surface of the water). This work will enable the prediction of close ship-whale encounters given different combinations of detected and/or missed cues at varying ship speeds. It will support ship operators' avoidance efforts by quantifying the availability and detection processes in a way that facilitates the development of whale avoidance protocols.

**Estimating Migratory—Resident Elk Populations and Juvenile Recruitment Using Remote Cameras in the Canadian Rockies (Poster)

Mateen A. Hessami*, Wildlife Biology Program, University of Montana, Missoula
Mark Hebblewhite, Wildlife Biology Program, University of Montana, Missoula

The use of remote cameras has been at the forefront of debate in the sphere of wildlife population estimates. There is research suggesting camera surveys underestimate ungulate populations, however, with a second component of estimation, such as years of GPS points from collared elk, modeling a population and estimating resident elk calf recruitment and juvenile survival can become quantifiable. During the summer of 2016 I initiated an undergraduate research project under Dr. Mark Hebblewhite's ungulate ecology lab. Over the span of the summer, I deployed 28 remote cameras in a previously sampled large carnivore occupancy grid. The study area is the Ya Ha Tinda Ranch, adjacent to Banff National Park, Alberta. The purpose of my project is to estimate migratory—resident elk populations and juvenile recruitment utilizing remote cameras. Estimating ungulate populations is technical, expensive, and often a dangerous (helicopter surveys) task. As the ecology community evolves into safer, less invasive and more cost effective methods for population estimates, it is up to the wildlife research community to produce evidence that such methods are effective. My research is attempting to do just that with 88 collared individuals inhabiting the study area, *spatially explicit mark re-sight models* can be quantifiable in measuring non-uniquely identifiable ungulate populations across a landscape. The potential scientific impacts and applications resulting from my research project would be significant. A publication detailing how an elk population— with collared and uncollared individuals can be estimated strictly with remote wildlife cameras and would be a contribution in the desired direction of population ecology for less invasive, yet highly accurate and efficient population studies.

Bighorn Sheep Male Versus Female Use of Mineral Licks Within Glacier National Park (Poster)

Brandon L. Kittson*, Salish Kootenai College, Pablo, MT and USGS Northern Rocky Mountain Science Center, West Glacier, MT
Tab A. Graves, USGS Northern Rocky Mountain Science Center, West Glacier, MT

Little is known about the behavior of bighorn sheep when it comes to their use of mineral licks, including which groups frequent and utilize these licks the most. In the research, we used for this poster, we deployed a remote camera at a mineral lick within Glacier National Park near the Blackfeet Reservation. We analyzed 6124 photos using the Timelapse2 software. We then classified visits by ten minute intervals. We counted the maximum number of sheep by age class and sex within the ten-minute period, for sampling in 2014 and 2015. The results show a clear indication that this lick is used far more heavily by ewes and lambs than rams. This implies that this mineral lick is a particularly important resource for ewes and juvenile sheep. Further studies could provide more information on population dynamics and provide invaluable information that could possibly aid in management strategies.

Using Emerging Technologies to Bolster Long-Term Monitoring of Wetlands (Poster)

Mary Levandowski*, Ecology Department, Montana State University, Bozeman
Andrew Ray, Greater Yellowstone Network, National Park Service, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman
Adam Sepulveda, United States Geological Survey, Bozeman
Shan Burson, Grand Teton National Park, Moose, WY
Robb Diehl, United States Geological Survey, Bozeman, MT
Kristin Legg, Greater Yellowstone Network, National Park Service, Bozeman, MT

Freshwater wetlands support a disproportionately high diversity of species relative to other ecosystems and they are particularly vulnerable to climate change. Across Grand Teton and Yellowstone National Parks, wetlands represent just 3% of the landscape, yet 70% of Wyoming bird species and all native amphibians in the region use wetlands for some stage of their life. The Greater Yellowstone Inventory and Monitoring Network has monitored amphibians in wetlands since 2006 and found that over 40% of the region's isolated wetlands are dry in years with above average temperatures and reduced precipitation. Adding novel technologies to these monitoring efforts will increase our understanding of species diversity in wetlands susceptible to drying. We outfitted three wetland sites in Grand Teton National Park with acoustic (i.e., audible and ultrasonic) monitoring technology and wildlife camera traps in summer 2016. We collected data over a four-week period to test the efficacy of automated technology for wetland monitoring. Based on preliminary results from the ultrasonic monitoring and wildlife cameras, we detected four times more species with these tools, when compared to visual surveys of amphibians alone. Additionally, automated methods allowed us to detect species over a longer time window than feasible with visual surveys. We will continue our work in 2017, using environmental DNA, acoustic monitoring, and wildlife camera traps to capture information about a broader diversity of taxa using wetlands, to expand and enrich current monitoring efforts.

Restoration Plan for Sharp-Tailed Grouse Recovery in Western Montana (Poster)

Lance McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Brent Cascaddan, Department of Ecology, Montana State University, Bozeman
Alyson Hicks-Lynch, Department of Animal and Range Sciences, Montana State University, Bozeman
Megan Milligan, Department of Animal and Range Sciences, Montana State University, Bozeman
Alicia Netter, Department of Animal and Range Sciences, Montana State University, Bozeman
Sarah Otto*, Graduate School, Montana State University, Bozeman
Jarrett Payne, Department of Animal and Range Sciences, Montana State University, Bozeman
Skyler Vold, Department of Animal and Range Sciences, Montana State University, Bozeman
Smith Wells, Department of Animal and Range Sciences, Montana State University, Bozeman
Sam Wyffels, Department of Animal and Range Sciences, Montana State University, Bozeman

Sharp-tailed grouse are abundant east of the continental divide in Montana, however western populations were extirpated during the last century. Previous translocations of sharp-tailed grouse to prevent the collapse of western populations were unsuccessful. Interest in restoring sharp-tailed grouse to western Montana has persisted and spurred preliminary habitat evaluations of potential restoration sites. However, information is needed to inform recovery goals and develop a restoration program for the species in western Montana. At the request of Montana FWP, we developed a restoration plan that 1) evaluates the potential of identified restoration sites to support a reintroduced population of sharp-tailed grouse, and 2) describe actions needed to establish and manage a successful reintroduction of populations in western Montana. Our analyses of ecological and demographic requirements, suitability of available and potential habitat conditions, and population viability of sharp-tailed grouse indicated that a viable population of sharp-tailed grouse is likely not possible at identified recovery sites under current habitat conditions. However, population restoration in western Montana is possible with a concerted and sustained effort by multiple entities, and that the most suitable site for initial recovery efforts is within the Blackfoot Valley. We identified habitat limitations that should be addressed prior to reintroductions and developed prescriptions for population translocations and recovery, including protocols that minimize translocation-related mortalities, reduce movements away from the initial release sites, facilitate the quick establishments of leks, and assure sufficient genetic variation of founders to prevent genetic bottlenecks and inbreeding.

**Sparrow Dispersal as an Agent of Disease Transmission (Poster)

Tina Pantano*, Biology Department, Montana Tech, Butte
Hannah Butorovich, Biology Department, Montana Tech, Butte
Stella Capoccia, Biology Department, Montana Tech, Butte

This project tracks the movement of the Eurasian House Sparrow (*Passer domesticus*) as a potential vector for disease, specifically between backyard chicken coops. Controlled studies show that sparrows and chickens easily transmit a host of diseases between species, including the avian flu, E.coli (Escherichia coli), and Salmonella, many of which are also transmittable to humans. There hasn't been a lot of research that tracks the movement of sparrows, especially between chicken coops as feeding stations. Our hypothesis is that sparrows use multiple chicken coops as feeding sites, thereby serving as a vector for disease. This research will help improve the scientific understanding for the potential impact sparrows could have, by being a vector for transmission to chickens, as well as other species, by the use of the different coops as feeding sites. Using traps designed specifically for sparrows,

we captured the birds at 15 sites in the urban area of Butte-Silver Bow County. We then used colored leg bands to identify the birds based on location and age, and developed a number system to account for individuals. As the research progressed, increased movement between locations was observed. In conclusion, by tracking the movement of sparrows we can explain the extent to which backyard chicken coops are connected, and thereby investigate the vulnerability of the chickens to disease transmission

**Targeted Cattle Grazing to Enhance Sage-Grouse Brood-Rearing Habitat (Poster)

Jarrett M. Payne*, Animal and Range Sciences Department, Montana State University, Bozeman
Jeffrey C. Mosley, Animal and Range Sciences Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman
Brent L. Roeder, Teton County Extension, Montana State University, Choteau
Tracy K. Mosley, Park County Extension, Montana State University, Livingston
Lance B. McNew, Animal and Range Sciences Department, Montana State University, Bozeman
Hayes B. Goosey, Animal and Range Sciences Department, Montana State University, Bozeman

Often, greater sage-grouse (*Centrocercus urophasianus*) brood-rearing habitats dominated by dense mountain big sagebrush (*Artemisia tridentata vaseyana*; >10-25% canopy cover) limit important forbs and arthropods sage-grouse rely on during summer. We investigated whether protein supplementation could concentrate cattle during fall to reduce sagebrush canopy cover and increase the diversity and abundance of forbs and arthropods. We applied targeted cattle grazing within three large, contiguous pastures in the Beaverhead Mountains of southwestern Montana. In each pasture, we selected one 4-ha macroplot of dense sagebrush (>30%). Within each macroplot, we placed low-moisture block protein supplement in four microsites (78.5-m2) and compared cattle response to four untreated control microsites. The following summer we measured herbaceous canopy cover and composition, shrub canopy cover, ground cover, forb and arthropod diversity, and arthropod density for each treated and untreated microsites. Mountain big sagebrush canopy cover was 71% less in treated vs. untreated microsites (11% vs. 38% canopy cover, respectively; $P < 0.001$). Bite count observations indicated that sagebrush cover was reduced by cattle trampling rather than browsing, as sagebrush comprised <1% of cattle diets. Forb diversity was 13% greater in treated microsites ($P = 0.094$), forb species richness was 16% greater in treated microsites ($P = 0.044$), and forb composition trended higher in treated microsites (45% of herbaceous composition in treated microsites vs. 32% in untreated microsites; $P = 0.106$). Lepidoptera density trended 18% greater in treated microsites ($P = .133$). Our results indicate that protein supplementation during late fall can concentrate cattle to enhance sage-grouse brood-rearing habitat.

**Assessing Habitat Quality for Four Grassland Songbird Species of Concern in Northern Philips County Montana (Poster)

John Pulliam*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance McNew, Department of Animal and Range Sciences, Montana State University, Bozeman

Over the last 40 years, grassland bird populations have declined faster than any other avian guild in North America. In northern Montana, four species are experiencing particularly dramatic population decline, Baird's Sparrow (*Ammodramus bairdii*), Sprague's Pipit (Anthus spragueii), Chestnut-collared Longspur (*Calcarius ornatus*), and McCown's Longspur

(*Rynchophanes mccownii*), all four are classified as species of concern in Montana. The primary threat to grassland birds is thought to be habitat degradation and fragmentation due to conversion of native prairie to farmland, energy development, and exurban development. The majority of the remaining native prairie is maintained for cattle grazing, either on private ranches or on public land that is then leased out to private ranchers. Informed management on native prairie has the potential to maximize habitat value for vulnerable species, however, currently we are still lacking the necessary information to design management strategies. Previous studies have attempted to describe quality habitat for grassland songbirds, defining quality, as conditions supporting a high density of adults successfully producing offspring. However these studies typically focus at the individual nest scale, habitat quality definitions at a scale useful to management are still poorly described. This study will attempt to fill this gap in knowledge, its objectives are 1) evaluate how local and pasture-level vegetation conditions affect nest survival for our focal species, 2) evaluate the effects of vegetation composition and structure on bird abundance and nest density, and 3) Evaluate the functional relationships among abundance, nest density, and nest survival.

**Testing an eDNA marker for Common Snapping Turtles (Poster)

Jakob Ritzdorf*, Kalispell Middle School, Kalispell, MT
Chris Hammond*, Montana Fish Wildlife and Parks, Kalispell
Kellie Carim, USFS National Genomics Center for Wildlife and Fish Conservation, Missoula, MT
Thomas Franklin, USFS National Genomics Center for Wildlife and Fish Conservation, Missoula, MT

Common snapping turtles (*Chelydra serpentina*) are a species of concern in southeastern Montana and some southern states; however, they are invasive to the Crown of the Continent ecosystem. Although raccoons and foxes destroy over 90% of the eggs, the few remaining survivors that reach adulthood are enough to raise serious concern as they prey upon many native species and have no natural predators. According to the Montana Natural Heritage Program, there have been only three documented reports of snapping turtles in the Flathead Valley, yet we have observed an additional 19 unreported individuals. We tested a previously developed environmental DNA (eDNA) marker for common snapping turtles to help determine their distribution in the Flathead Valley. We extracted DNA from snapping turtle tissue samples collected in the Flathead Valley to verify marker effectiveness. We hypothesized McGilvray Lake and a nearby small pond would be positive for snapping turtle DNA, while Spencer Lake would be negative. Painted turtles (Chrysemys picta belli) were visually detected in all of the waterbodies while snapping turtles have not been observed in Spencer Lake. We collected eDNA samples via water filtration in December 2016. All of the eDNA samples were negative for snapping turtle DNA. We believe our analysis produced negative results because during the winter the turtles bury themselves in the mud and the DNA can degrade or that we did not capture enough DNA. We plan to sample in the summer when the turtles are more active to increase our probability of detection.

**Carnivore Territoriality: Simulating Economic Selection of Territories (Poster)

Sarah N. Sells*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Michael S. Mitchell, USGS Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Angela D. Luis, Wildlife Biology Program, University of Montana, Missoula
Kevin M. Podruzny, Montana Fish, Wildlife and Parks, Helena

We are developing theoretical models of territorial behavior of carnivores. This work will be useful for predicting the abundance of wolf (*Canis lupus*) territories in Montana and Idaho. Coupled with a patch occupancy model, it will provide more accurate estimates of abundance of wolves in each state. Ultimately, our work will also provide a better understanding of territorial behavior of a large carnivore. We are simulating the territory selection process for carnivores choosing patches on a landscape based on benefits of prey, where prey distribution ranges from overdispersed to highly clumped. Simulated carnivores will also consider hypothesized costs of patch ownership, including travel, competition, and mortality risk. In each simulation, carnivores will acquire patches for a territory as economically as possible based on these benefits and costs. Simulating various combinations of these hypothesized benefits and costs of patch ownership will provide predictions of territorial behavior. We can then compare these predictions to the territories of real wolves to determine which model is most predictive of actual wolf behavior. Starting with a model for benefits of prey and costs of travel, we found that prey distribution may influence mean size, quality, and fragmentation of simulated territories. Based on these preliminary results, we might expect differences in size or quality of territories in regions with different prey communities. Most importantly, this work provides a foundation from which we will build more complex models of territorial behavior of carnivores.

Birds, Herps, and Small Mammals! Oh, My! Help FWP Find Rare and Elusive Species (Poster and Oral Presentation)

Brandi Skone*, Montana Fish Wildlife and Parks, Miles City
Heather Harris*, Montana Fish Wildlife and Parks, Glasgow
Lauri Hanauska-Brown, Montana Fish Wildlife and Parks, Helena
Allison Begley, Montana Fish Wildlife and Parks, Helena
Kristi DuBois, Montana Fish Wildlife and Parks, Missoula
Claire Gower, Montana Fish Wildlife and Parks, Bozeman
Chris Hammond, Montana Fish Wildlife and Parks, Kalispell
Megan O'Reilly, Montana Fish Wildlife and Parks, Billings
Kristina Smucker, Montana Fish Wildlife and Parks, Great Falls

In 2014, Montana Fish, Wildlife & Parks (MFWP) expanded their Nongame Program to include a Wildlife Biologist specializing in nongame species work in every region. Although each region has different priorities, the goals within the Nongame Program are universal: (1) Keep common species common, (2) Reverse population declines for species of concern, and (3) Foster awareness and enhance public knowledge and appreciation of nongame species. Our efforts are guided by the State Wildlife Action Plan (SWAP) which prioritizes work on habitats and species of greatest conservation need. These efforts include anything from developing habitat conservation projects to surveying single species. Within the SWAP there are a number of species considered Species of Greatest Inventory Need because they lack

sufficient data to determine their status. Often these species are rare, elusive, or difficult to observe. Consequently, we seek the help of others to provide incidental observations in addition to our structured survey efforts. Some of our high priority species include: (1) black rosy-finch, a small high-alpine songbird, (2) greater short-horned lizard, a cryptic reptile dependent on sparse habitat, (3) black-tailed jack rabbit, a lesser-known lagomorph found in open country habitat, and (4) black swift, the largest of the swift species, nesting secretively in shallow caves and behind waterfalls. People interested in assisting with surveys should contact the appropriate FWP nongame lead. By working together, we can provide managers and regulatory agencies with vital information to make well-informed decisions about our valued resources in Montana.

**Understanding how Characteristics of the Nest Site Affect Nest Success of Wild Turkeys (Poster)

Thomas A. Sutton*, Ecology Department, Montana State University, Bozeman
Michael J. Yarnall, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman

Wild turkeys (*Meleagris gallapavo*) are a highly-desirable game species throughout the United States, but harvest records in the northern Black Hills, South Dakota suggest that this population is declining. We wondered whether vegetation characteristics at the nest site would affect nest fate (success/failure). We monitored 40 nests during summer 2016 to determine nest fate and 27 were successful (≥1 egg hatched). At the actual or expected hatch date, we quantified characteristics of the understory vegetation at the nest bowl, namely total cover, shrub cover, woody debris, and the degree of visual obstruction. We compared these characteristics between successful and unsuccessful nests. Successful nests had slightly less woody debris and total cover than unsuccessful nests. We did not detect differences in shrub cover or the degree of visual obstruction. Our results suggest that there may be some optimal amount of total cover and woody debris at the nest bowl that contributes to a higher chance of nest success. We recommend additional research that focuses on how vegetation characteristics found at nest sites compares to what is available. This information in conjunction with our findings could provide guidance for managers regarding vegetation characteristics that may be optimal for nest success. Although these data may help manage turkey populations, nesting represents only one part of the life cycle of a wild turkey. We recommend that managers strive for a mosaic of vegetation characteristics to accommodate the needs of turkey populations throughout their life history.

** Effects of Livestock Grazing Management on Grassland Bird Abundance in the Northern Mixed-Grass Prairie (Poster)

Skyler T. Vold*, Department of Animal and Range Sciences, Montana State University, Bozeman
Lance B. McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Lorelle I. Berkeley, Montana Fish Wildlife and Parks, Helena

Grassland bird populations have been declining throughout a majority of their range in the United States and Canada over the past 40 years, and currently have the most accelerated declines of any guild of terrestrial birds in this region. Rangelands used for domestic cattle grazing are important for maintaining large tracts of native grassland that may otherwise be converted to agricultural use or other human development. In addition, grassland birds respond well to livestock grazing systems that increase habitat heterogeneity by mimicking

historic grassland disturbance, such as fire and bison grazing. Montana Department of Fish, Wildlife, and Parks (FWP) implements a rest-rotation grazing system within conservation easements to increase structural heterogeneity of grassland vegetation on the landscape. However, the rest-rotation grazing system administered by Montana FWP was developed for more arid, bunchgrass-dominated rangelands and has not been evaluated as a management tool for creating structurally diverse wildlife habitat in the northern mixed-grass prairie. This study examines the effect of a rest-rotation grazing system on breeding season habitat selection and abundance of four native grassland songbird species, Baird's sparrow (*Ammodramus bairdii*), grasshopper sparrow (*Ammodramus savannarum*), vesper sparrow (*Pooecetes gramineus*), and western meadowlark (*Sturnella neglecta*), relative to traditional season-long or rotational grazing systems on a Montana FWP conservation easement in eastern Montana. Our objectives for the study are: 1) evaluate how abundance and space-use of four focal grassland bird species are affected by grazing treatment; 2) estimate the importance of habitat and vegetation characteristics for focal species within pasture treatments; 3) offer management recommendations to agencies and private landowners for improving grassland bird abundance and habitat quality.

**Combining Radio-Telemetry with Stable Isotope Techniques to Determine Wintering Origin of Greater Sage-Grouse (Poster)

James A. Waxe*, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman
Kyle A. Cutting, USFWS Red Rock Lakes NWR, Lima, MT
Bok Sowell, Animal and Range Sciences Department, Montana State University, Bozeman

Much of Greater Sage-grouse conservation is focused on improving habitat around lekking areas, but distant wintering habitat may contribute equally to the viability of populations, a pattern that has been shown with other avian taxa. On-going research in the Centennial Valley in southwestern Montana has tracked 182 female Sage-grouse throughout the year with VHF radio-telemetry collars. Based on this work, we have observed individuals move as little as 0.73 km or as far as 79.2 km from their lek to wintering grounds (mean distance = 23.8 km). We also have learned that some individuals exhibit high fidelity to wintering sites across years. We aim to better understand the importance of wintering grounds on life history of Greater Sage-grouse. We will identify wintering origin of individual females using radio telemetry and stable isotope techniques and assess the influence of wintering grounds on reproductive success. Our findings will help managers identify seasonal habitats contributing to reproductive success, areas critical to Sage-grouse conservation in southwestern Montana and southeastern Idaho that may have been previously overlooked. These techniques also could be effective in other regions where Sage-grouse exhibit long distance, seasonal movements.

In-Hand Measurements of Adult Bats in the Northern Great Plains and Rocky Mountains (Poster)

Ellen M. Whittle*, Montana Natural Heritage Program, Helena
Daniel A. Bachen, Montana Natural Heritage Program, Helena
Bryce A. Maxell, Montana Natural Heritage Program, Helena

Researchers rely on keys and other published records of pelage and morphological characteristics to identify bat species in the field. However, these records may not reflect the variability of measurements taken in a field setting, particularly if they are based upon museum specimens or a small number of live individuals. To assist in the identification of

similar bat species, we created a supplement to the "Key to Idaho, Montana, and South Dakota Bats." We compiled 3,222 records of 11 species of adult bats captured between 1994-2016 in Montana, northern Idaho, and northwestern South Dakota. Using this dataset, we have provided distributions of body measurements as well as insight into the timing of reproduction, parturition, and seasonal body condition for 14 of the 15 species occurring within Montana. Following data analyses, we concluded that: (1) lengths of smaller appendages such as the thumb and tragus show substantial variation, demonstrating that more precise measurements are required; (2) parturition dates appear similar across all species present in the study area, including migratory bats; (3) trends of low body mass in late summer captures may represent older juveniles that are difficult to distinguish from adults by current methods; and (4) we require more data to analyze the traits of species that are infrequently captured. This document will be available on the Montana Natural Heritage Program website (mtnhp.org) to assist researchers in the field.

Montana Academy of Sciences

2017 Annual Meeting

April 7-8, 2017

Montana Tech of the University of Montana - Butte, Montana

James G. Berardinelli, President, Montana Academy of Sciences
James Barron, Executive Director, Montana Academy of Sciences

INTRODUCTION

The Montana Academy of Sciences (MAS) was incorporated on the 20th day of March, 1961, as a non-profit, educational organization. The objectives of the Montana Academy of Sciences are to encourage interest and participation in the sciences and to promote public understanding of science and its contribution to society. The Academy accomplishes its objectives by conducting meetings of those interested in sciences and the education of scientists, by publishing contributions to scientific knowledge, by supporting research, by making awards to recognize accomplishments in science, by administering gifts and contributions to accomplish these aims, by assigning and cooperating with affiliated and other organizations with similar objectives, and by engaging in such other activities as deemed necessary to accomplish its objectives.

We held our 2017 Annual Meeting at Montana Tech in Butte, MT. on April 7 and 8. Over 100 registrants participated, viewing 22 contributed oral presentations and 20 poster presentations over the day and a half meeting. We present the abstracts from our meeting here so that the readers of the Intermountain Journal of Sciences can see the quality and types of science supported by MAS. Please mark your calendars for our next meeting, April 6 and 7, 2018 in Butte. Finally, the Board of Directors of MAS would like to thank the sponsors of our 2017 Annual Meeting:

Dr. Doug Coe, Dean, College of Letters, Sciences and Professional Studies, Montana Tech

Dr. Beverly Hartline, Vice Chancellor for Research, Montana Tech

Dr. Renee Reijo Pera, VP for Research, Montana State University

Dr. Beth Weatherby, Chancellor, University of Montana – Western

Dr. Tim Laurent, Provost and VP for Academic Affairs, University of Great Falls

Department of Biological and Physical Sciences, Montana State University – Billings

Presentation Abstracts

Alphabetical by First Author's Last Name

Characterization and Classification of a Montana Mycobacteriophage

Margeaux Black, Montana Tech of the University of Montana, Butte

Froghopper, a Mycobacteriophage discovered by Nikki Boyd in 2005 and stored in Dr. Marisa Pedulla's collection, was adopted in the fall of 2016. The bacteriophage was plated, or used to infect *Mycobacterium smegmatis* on Petri dishes, in order to determine the morphology of the resultant plaque. Froghopper was purified and amplified, and a high titer stock was made. DNA of the phage was extracted using phenol/chloroform. Restriction digests and agarose gel electrophoresis of Froghopper DNA were performed in order to compare the DNA of Froghopper to DNA of phages in the Actinobacteriophage database. The polymerase chain reaction (PCR) was used for preliminary determination of Froghopper's phage cluster. A phage cluster is a group of bacteriophages with similar DNA sequences. Phage clusters can be predicted by a set of primers used in PCR to determine genetic similarities to sequenced bacteriophages (Smith et al., 2013). Determination of the bacteriophage's structural morphology was determined by imaging the phage under transmission electron microscopy at the University of Montana. DNA of the bacteriophage was sent to the University of Pittsburgh for the DNA sequencing. Once sequenced, the DNA sequence was annotated; putative protein coding genes were identified and described in relation to other known sequences, and the annotated sequence was submitted to GenBank.

Fabrication and Characterization of Aligned Fibers on Nonconductive Substrates from a Novel Electrospinning System

Zachary Burckhard, Mechanical Engineering and Montana Tech Nanotechnology Laboratory, Montana Tech of the University of Montana, Butte
Jack L. Skinner, Mechanical Engineering and Montana Tech Nanotechnology Laboratory, Montana Tech of the University of Montana, Butte

Electrospinning has become a valuable technique for producing micro-to-nanoscale polymeric fibers with length scales from ~1 nm to 100 μm. Alignment of electrospun fibers further expands upon functionality by increasing reproducibility and improving predictive behavior of fibers in various environmental conditions. The utility of electrospun fibers can be subsequently increased with the ability to deposit directly onto a non-conductive/non-energized surface. Possible uses include displays and sensors for commercial or defense applications or in biomedical application for depositing on tissue. In order to accurately deposit electrospun fibers onto a nonconductive surface, we developed a new electrospinning apparatus. The set up for the device includes two grounded electrodes separated with a small gap that sheets of air were be forced through in order to prevent the fibers from contacting the electrodes. Fibers were deposited directly onto a nonconductive surface placed below the grounded electrodes. Details of the apparatus along with images and analysis of resultant fibers will be presented.

Rhetoric, Visual Rhetoric, and the 1950'S Betty Crocker Cookbooks

Barbara Cass, Professional and Technical Communication, Montana Tech of the University of Montana, Butte

This study explores the importance of Betty Crocker to her cookbooks in the 1950's. The Betty Crocker Cookbook was an instruction manual that fits within a particular genre of technical communication. These technical manuals included instruction for women on how to prepare and cook aesthetically pleasing and wholesome meals. The Betty Crocker Cookbook went beyond established norms of cookbook instruction by adding helpful hints on how to be a perfect housewife. Rhetorical and visual analysis of the 1950's Betty Crocker Cookbooks shows the importance of these particular cookbooks was Betty Crocker herself. Because she was an authority on all things pertaining to the kitchen, women accepted this authority, in part because of the ethos of Betty Crocker, a trusted figure and someone they felt a relationship with. She was with them through the Great Depression and World War II, and she was the voice on the radio that brought a sense of normalcy in a turbulent time, the fact that Betty Crocker was a fictional construct did not matter.

Rabbit Creek: Geochemistry of an Alkaline Deeply Sourced Hot Spring with Abundant Microbial Mats

Jordan Foster, LEGEND Lab, Department of Chemistry & Geochemistry, Montana Tech of the University of Montana
Shanna Law, LEGEND Lab, Department of Chemistry & Geochemistry, Montana Tech of the University of Montana
Mallory Nelson, LEGEND Lab, Department of Chemistry & Geochemistry, Montana Tech of the University of Montana
Georgia Dahlquist, LEGEND Lab, Department of Chemistry & Geochemistry, Montana Tech of the University of Montana
Alysia Cox, Department of Chemistry & Geochemistry, Montana Tech of the University of Montana

The Rabbit Creek hot springs in Yellowstone National Park are located along the edge of the Mallard Lake Dome in the Midway Geyser Basin. The principal source, Rabbit Creek hot spring, contains high concentrations of arsenic and antimony relative to hot springs throughout the area. This study investigates the water chemistry of the Rabbit Creek hot spring outflow, geologic explanations for the distinct differences in hot spring compositions of the area, and the implications for the abundant thermophilic microbial mats present in the outflow. The distribution of the microbial mats may be related to the concentrations of arsenic and antimony throughout the outflow. In addition, changes in the microbial mats related to temperature and sulfide concentrations are discussed. This study aids in our understanding of the hot springs in the Rabbit Creek area and of the potential effects of the Mallard Lake Dome on the Midway Geyser Basin.

Separation Features of Fine Particle Processing in a Crossflow Separator

John Hansen-Carlson, Department of Metallurgical and Materials Engineering, Montana Tech of the University of Montana, Butte
Avimanyu Das, Department of Metallurgical and Materials Engineering, Montana Tech of the University of Montana, Butte

A Cross Flow Separator works on the principle of hindered settling and liquid fluidization to accomplish gravity concentration of fine particulate mass. Heavier particles penetrate the fluidized suspension to settle at the bottom to be discharged as the underflow while the lighter particles remain at the top and are carried away by the upward flowing water to the overflow outlet. Influence of bed depth, feed rate and teeter water flow rate on the separation features along with the response of feed particle size was investigated with reference to a difficult fine coal (1.4 x 0.1 mm) having 33% ash. Characterization of the feed was followed by a detailed experimental program using response surface methodology. Products of each experiment were characterized to understand the separation mechanism and how various particles respond to the process conditions. The process responses were estimated in terms of mass yield, ash levels of both products and combustible recovery. The experimental data were analyzed to arrive at statistically significant correlations for the response variables. The process was optimized and under optimum conditions, clean coal with 24% ash at 63% mass yield and over 70% combustible recovery was obtained. Overall Ep was 0.34 with an effective separation density of 1.81 g/cc. It was concluded that a ratio of 10:1 between the top and the bottom sizes of the particles may be acceptable in the feed material. The importance of the flow behavior was discussed. The process features were also described phenomenologically vis-à-vis the experimental observations.

Potential Factors Driving Sandberg's Bluegrass Growth In Relation to Sagebrush Cover

Nate Haygood, Montana State University, Bozeman
Clayton Marlow, Department of Animal and Range Sciences, Montana State University, Bozeman

Sandberg's bluegrass (*Poa secunda*) is a native perennial bunchgrass found throughout most of the Intermountain West. Like many other cool season bunchgrass species, Sandberg's bluegrass is a valuable and readily attainable forage as winter snowpack thaws and recedes. Because a large percent of Western North American rangeland is co-dominated by shrubs, it is paramount that land managers have an adequate and increasingly broad understanding of the biology and relationship between grasses and shrubs. With this in mind, we measured water availability, soil temperature, and basal area of Sandberg's bluegrass plants inside and outside of the sagebrush canopy as well as a simple plant count with the purpose of evaluating potential drivers behind growth and success of this species. Basal areas were significantly greater inside the canopy versus outside ($P = 0.033$) which was consistent with our hypothesis. Soil temperature was significantly lower inside the canopy versus outside ($P = 0.049$) while soil water content was not significantly different. However, there was no significant correlation between basal area and soil water content or soil temperature. We infer from the data collected that Sandberg's bluegrass is indeed more robust and numerous within the canopy of sagebrush compared to outside the canopy; however, the primary driver for this is still unclear. It is our conclusion that future research is needed in order to evaluate and identify the reason for this occurrence.

Macroinvertebrates as Indicators of Water Quality in Blacktail Creek

Ryan Koch, Department of Biological Sciences, Montana Tech of the University of Montana, Butte
Stella Capoccia, Department of Biological Sciences, Montana Tech of the University of Montana, Butte
Mark Mariano, Department of Biological Sciences, Montana Tech of the University of Montana, Butte

Blacktail Creek, located in Butte, Montana, has a long history of human-caused contamination. Mine waste has polluted parts of its streambed since the late 1800's, causing extensive loss of vegetative diversity along the creek, as well as a loss of aquatic life. The Blacktail Berm is an area currently estimated to contain 35,000 cubic yards of toxic mine tailings. The future removal of remaining mine tailings in Butte is not a certainty at this point, but planning removal and restoration of these contaminated areas has been discussed extensively in recent years. In order to help provide baseline data prior to future restoration efforts, this study was conducted to survey the aquatic macroinvertebrate populations in Blacktail Creek. Macroinvertebrates are often used as part of an assessment of stream health, particularly in relation to restoration work. The presence and abundance of specific aquatic macroinvertebrates can be used to get an idea of the water quality of the stream. Macroinvertebrate samples were collected at five locations along Blacktail Creek from September 13, 2016 through September 17, 2016. Along with stream conductivity, temperature, and dissolved oxygen, an Ephemeroptera, Plecoptera, and Trichoptera (EPT) index assessment was completed. The EPT index used for this assessment provided good, fair, or poor water quality ratings for Blacktail Creek based on the ratio of EPT macroinvertebrates to total macroinvertebrates in a single sample. The results will provide data useful in long-term monitoring of these macroinvertebrate populations before, during, and after the cleanup of Blacktail Creek.

Amphibian Risk Assessment in Montana

Alex Kurtz, Department of Biochemistry and Molecular Biology, Carroll College, Helena

The fungus, *Batrachochytrium dendrobatidis*, has been found to negatively impact amphibian populations around the world. This fungus can have multiple effects on frogs and salamander physiology, including changes in osmotic regulation that may lead to death. B. *dendrobatidis* has been shown to be the driving force for many amphibian population crashes and extinctions around the world. The purpose of this project was to build a predictive model of B. *dendrobatidis* infection, one that would be used to assess population susceptibility in order to identify populations of amphibians at risk of infection. This was accomplished by statistical analyses of several components that contribute to infection vulnerability, including amphibian antimicrobial peptide production, cutaneous bacterial colony structure, infection status for each frog and water nutrient composition. This project collected baseline data that will allow us to establish meaningful relationships between susceptibility factors and disease which will permit the identification of populations at risk. Although certifications may not provide a comprehensive solution to the challenges facing women in Costa Rica's coffee industry, the majority of women feel empowered through involvement in local organizations and women's groups. This research adds new perspectives to the growing body of literature regarding the efficacy of coffee certification schemes and has implications for certification agencies and local-level organizations in Costa Rica and other coffee producing countries.

Using Nuclear Magnetic Resonance (NMR) Metabolic Profiling to Distinguish Herds of Bighorn Sheep

Melissa Lambert, Department of Animal and Range Sciences, Montana State University, Bozeman
Jesse White, Department of Animal and Range Sciences, Montana State University, Bozeman
Valerie Copie, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Brian Tripet, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Carson Butler, Ecology Department, Montana State University, Bozeman
Robert Garrott, Ecology Department, Montana State University, Bozeman
James G. Berardinelli, Department of Animal and Range Sciences, Montana State University, Bozeman

The objective of this study was to determine if nuclear magnetic resonance (NMR) metabolic profiling has the potential to serve as a management tool for evaluating herds of bighorn (*Ovis canadensis*) sheep. Two-hundred and forty bighorn sheep serum samples from 13 herds located in Montana and Wyoming were processed for NMR spectra, profiled for small molecule metabolites using Chenomx®, and then analyzed with MetaboAnalyst (v3.0). Fifty-six small molecule metabolites were identified in ungulate serum. To determine if NMR metabolic profiles can distinguish herds that are geographically distinct with access to different nutritional resources, herds collected in December were compared to herds collected in March. Partial least square discriminant analysis (PLS-DA) indicated a clear, majority separation of metabolic shifts with minor overlaps. Biomarker analysis identified 15 potential biomarkers from the compounds with variables of importance (VIP) scores greater than 1.0. These molecules enabled us to identify 'significantly' important metabolic pathways that discriminate herds sampled in December and herds sampled in March. Key biomarkers resulting from the pathway analysis, included: 2-oxoisocaproate, choline, tyrosine, creatinine, and trimethylamine n-oxide. To determine if metabolic profiling can distinguish individual herds within a month, herds in December, January and March were compared to a domestic, Rambouillet ewes (control) sampled during the sample months. PLS-DA of all herds showed clear metabolic shifts and complete separation between each individual herd and the control ewes for each month. Potential biomarkers for herds within a season that were found to be good discriminants for the December herds included: trimethylamine n-oxide and sarcosine; for January herds included: creatinine and asparagine; and, for March herd included, creatinine. Through identification of small molecule metabolites, it is possible to discriminate herds from each other within and between seasons. These biomarkers represent a potential panel of metabolites that may be used for assessing nutritional status, environmental stress, and herd health through the identification of significantly important metabolic pathways related to energy and protein balance.

High Saturated Fat-Enriched Diet Evokes Endoplasmic Reticulum Stress and Consequently Increases β- Site App Cleaving Enzyme 1 Activity in Amyloid-Beta Engenderment in the Brain

Gurdweep Marwarha, School of Medicine & Health Sciences, University of North Dakota, Grand Forks

Othman Ghribi, Department of Biomedical Sciences, School of Medicine & Health Sciences, University of North Dakota, Grand Forks

Alzheimer's disease (AD) is the most common form of dementia in the elderly that is histo-pathologically characterized by extracellular accumulation of aggregated Amyloid-β (Aβ) peptide as neuritic senile plaques and the intracellular accumulation of aggregated hyperphosphorylated protein tau (τ) as neurofibrillary tangles. The aspartyl protease BACE1 is indispensable for the engenderment of Aβ and catalyzes the rate-limiting step in Aβ genesis from AβPP. The expression of BACE1 protein as well as its enzymatic activity is significantly augmented in the AD brain. The etiology of AD is multifactorial and egregiously comprehended, but epidemiological studies have implicated a diet rich in saturated free fatty acids (sFFA) as a significant risk factor for developing AD. Palmitic acid (palmitate) is the most abundant long-chain free saturated fatty acid in the brain and the diet and higher palmitate levels in the plasma, as observed in obesity and diabetes, inversely correlate with cognitive function. Recent cogent evidence has implicated endoplasmic reticulum (ER) stress as one of the culpable factors in initiating and fostering the deleterious neurodegenerative changes in AD. A multitude of studies have cogently demonstrated that sFFA such as palmitic acid evoke ER stress. In this study we demonstrate that palmitate evokes ER stress leading to the induction of CHOP expression which indispensably mediates the up-regulation in BACE1 expression and Aβ engenderment via the NF-κB signaling pathway. Our study unveils a novel ER stress/CHOP/NF-κB signaling pathway and delineates the molecular mechanism thereof that mediate the palmitate-induced up-regulation of BACE1 expression.

Design and Synthesis of Proligand Pyridine-2,6 Dithiocarboxylic Acid and Structural Derivatives for Use in Environmental Remediation of Carbon Tetrachloride

Ky Mickelson, Department of Chemistry and Biochemistry, Montana State University, Bozeman

Thomas Livinghouse, Department of Chemistry and Biochemistry, Montana State University, Bozeman

Matt Queen, Department of Biological and Physical Sciences, Montana State University – Billings, Billings

Thomas Lewis, Department of Biological and Physical Sciences, Montana State University – Billings, Billings

Carbon Tetrachloride is a carcinogenic pollutant that has contaminated groundwater beneath former grain storage and industrial sites, such as the Department of Energy's Hanford site. Current remediation of these sites involve removal and subsequent treatment, which requires handling of the hazardous material as it is transferred to another location for final destruction. Professor Thomas Lewis has previously described the use of a small molecule (pyridine-2,6-dithiocarboxylic acid [PDTC]), that when complexed with copper has been shown to lead to complete dechlorination of pollutant carbon tetrachloride within atmospheric samples. The process results in conversion to non-toxic end-products (mostly

CO2) and complete removal of the problematic carbon-chlorine bonds. Synthetic chemistry can be employed to develop a series of PDTC derivatives that could increase water solubility and allow for on-site destruction of carbon tetrachloride. The current methods described in literature for the synthesis of proligand PDTC uses or produces large quantities of toxic hydrogen sulfide gas. A modified procedure for large-scale production of PDTC, with minimal hydrogen sulfide production, was successfully developed. However, this method will not be able to be utilized for synthesizing derivatives of PDTC, which defines the need for a novel approach to the development of proligand derivatives. An elegant approach using a dilithiated addition into carbonyl sulfide is currently under investigation to produce PDTC and several derivatives that could be functionalized for use in environmental remediation of carbon tetrachloride.

Finite-Difference Modeling of 2-D Compressional Wavefield

Chau Duc Minh Ha, Mathematical Sciences Department, Montana Tech of the Universityof Montana, Butte

This project discusses the derivation of the 2-D compressional wavefield (P-wave) and its finite-difference approximation. In developing this wavefield, we have two approximations. First, the subsurface density is assumed to be a constant. Second, the angle of wave propagation is less than 150 with respect to the surface (horizontal direction). The algorithms are used to demonstrate the propagation of P-wave through a simple subsurface model. Although not discussed in this project, the same algorithms are also able to model the propagation of P-wave in another complex model and the success of depth-imaging algorithms in recovering the subsurface structures indicates the accuracy of the approximations for most modeling purposes. Future studies include modeling P-wave in 3-D, modeling elastic wavefield in 2/3-D, and extending the angle of propagation to more accurately model incoming waves at the edge of the computational grid.

Extension Theory in Coarse Geometry

Atish Mitra, Department of Mathematical Sciences, Montana Tech of the University on Montana, Butte

LSAEs (Large Scale Absolute Extensors) were introduced by J. Dydak and the author to study the coarse geometry of metric spaces. In this talk we will discuss how this concept can be used to study extensions of proper large scale Lipschitz functions between metric spaces.

Essentially Normal Composition Operators on the Hardy Space

Jeff Preston, Montana Tech of the University on Montana, Butte

Waleed Al-Rawashdeh, Department of Mathematical Sciences, Montana Tech of the University on Montana, Butte

In this presentation, we will explore composition operators on the Hardy space. We will investigate what it means for such composition operators to be essentially normal. The following question will be answered in this presentation: Are there any composition operators on the Hardy space which are essentially normal but which are not compact?

Growth of Finitely Generated Groups

Jeff Preston, Montana Tech at University of Montana, Butte
Atish Mitra, Department of Mathematical Sciences, Montana Tech of the University of Montana, Butte

Given a finitely generated group, we study various growth functions and growth series. We calculate growth functions for certain groups of polynomial and exponential growth, and study R. Grigorchuk's example of a group with intermediate growth. We examine relations between algebraic properties of a finitely generated group and the equivalence class of its growth functions.

Relationship of Athletic Injuries to Athletic Season

Jessica Ream, University of Great Falls, Great Falls

In the world of sport, to be an excellent athlete, one must have the necessary physical attributes, appropriate environment, and personality variables to succeed. However, a critical variable that affects every aspect of athletic ability is athletic injury. Injuries have negative consequences for the athlete's health, training, and competitive performance. Maintaining an absence of injuries is pivotal for the athletic individual and the team as a whole. This research characterizes the relationship between type and duration of athletic injuries in different sports and months of occurrence during the period 2012-2015. Archival data was collected from the University of Great Falls, Montana State University, and Westminster College. Due to the higher injury rates, the sports of focus were women's volleyball, women's softball, women's basketball, men's wrestling, and co-ed cheer. This presentation will summarize findings and implications for athletic trainers, coaches, and players.

Automating the Process of Fitting New Planetary Transit Data with Python

Ailey Robinson, Hellgate High School, Missoula

The study of exoplanets has aided astronomers in understanding the behaviors of solar systems and continued the search for extraterrestrial life. Photometry, the measurement of light flux caused by a planetary object transiting a star, is one of the main methods to detecting exoplanets. Because of atmospheric variations and experimental uncertainty, the photometric data is modeled with a line of best fit. To create the fit for the data, a person must input values for seven parameters iteratively until the accuracy of the fit is satisfactory. This process is time-consuming and limits the accuracy of the model. This project presents a new program coded in Python that will automate the process for new transit data by allowing a user to input one set of estimated parameters. The program alters the inputted parameters repeatedly to create multiple fits, and then presents the parameters for the fit with the lowest residual data. Planets with high chances of transiting their parent star were chosen for observation. Two planets with previously confirmed transits and thirteen planets without confirmed transits were observed using four, 0.7meter telescopes. Data were analyzed using the current method of data analysis and with the program developed in this project. This program could serve as a practical application for astronomers that provide more accurate and efficient results. The purpose of the experiment is to see how environmental and chemical factors, such as caffeine, induce different stress responses based off of zebrafish behavior and cortisol assay results.

Women's Experiences and Perspectives of Certification Schemes and Empowerment in the Costa Rican Coffee Industry

Laura Stein, W.A. Franke College of Forestry and Conservation, University of Montana, Missoula

Coffee certification schemes, such as Fair Trade, Rainforest Alliance, and Organic, influence the environmental, economic, and social conditions of the global coffee industry by promoting sustainable production practices and equitable trade relations. Over the past three decades, studies show that adhering to environmental standards supports ecological conservation in agricultural communities. However, research examining the economic and social impacts among producers yields mixed results due to context-specific factors such as management strategies, landholding size, and market conditions. Furthermore, although many certification schemes incorporate gender equality and women's empowerment initiatives, little attention has been given to the perspectives of women producers, many of whom confront challenges due to socially constructed gender norms. This research addresses this gap in knowledge through case study analysis of two organizations in southern Costa Rica: CoopeAgri, a mixed-gender producer cooperative, and ASOMOBI, an all-women's coffee association. Data were gathered through in-depth interviews, document analysis, and participant observation within each organization. Preliminary results suggest that while the majority of women believe certifications can provide benefits, there are significant costs (i.e., money, time, energy), and the actual benefits received can be minimal.

The Word Problem for Hyperbolic Groups

Tyler Taylor, Montana Tech at University on Montana, Butte
Atish Mitra, Mathematics Department, Montana Tech at University on Montana, Butte

Max Dehn's word problem asks us the following: Given a finitely generated group in terms of generators and relations, is there an algorithmic procedure to determine if an arbitrary word represents the identity element? In this undergraduate research project, we define the notion of hyperbolicity of a metric space and present a geometric proof that all hyperbolic groups have solvable word problems.

Continuous Nowhere Differentiable Functions

Tyler Taylor, Montana Tech at University of Montana, Butte
Waleed Al-Rawashdeh, Department of Mathematical Sciences, Montana Tech of the University of Montana, Butte

In this presentation we study functions that are continuous everywhere on their domain but differentiable nowhere. One such function is the function whose graph is called the Kiesswetter curve. First we construct the curve and the piece-wise function that represents that curve. We prove several key properties of the function that gives us insight to why this function is continuous on the unit interval. We then prove the continuity and non-differentiability of the function.

Poster Abstracts

Alphabetical by First Author's Last Name

Cardiac and Perceptual Responses to Performing Tandem Cardiopulmonary Resuscitation (Poster)

Jacob Bone, Department of Health and Human Performance, Montana State University-Billings
Alex Shafer, Department of Health and Human Performance, Montana State University- Billings

Introduction: Information regarding the physiological and perceptual response of the human body in the act of performing tandem cardiopulmonary resuscitation (CPR) relative to solo CPR is lacking. Purpose: The purpose of this investigation is to compare rescuer heart rate (HR), rating of perceived exertion (RPE), and CPR quality during Tandem-CPR and Solo-CPR. Methods: Thirteen healthy young adults (aged 26.5±4.3 yrs) were recruited from MSUB campus community. Participants completed two 6-minute bouts of CPR during a single session. Tandem and solo techniques were counterbalanced, with a 15-minute rest period separating the bouts. Values for HR and RPE were recorded using a Polar V800 HR monitor and Adult OMNI-RPE scale, respectively. A Laerdal Resusci-Anne CPR manikin was used to record compression score (0-100%), which is a value that incorporates compression rate and depth to illustrate CPR quality. Mean HR, peak RPE and CPR compression scores were examined with dependent t-tests between CPR techniques. Statistical significance was accepted at $p<0.05$. Results: Sample mean HR per bout was significantly lower in Tandem-CPR than in Solo-CPR (111.2±16.8 vs. 126.1±19.3, $p<0.0001$). Peak RPE was significantly lower during Tandem-CPR compared to Solo-CPR (3.2±2.0 vs. 5.0±2.5, $p<0.05$). Compression scores were significantly higher for Tandem-CPR when compared to Solo-CPR (96±3% vs. 94±5%, $p<0.05$). Discussion: Current findings call for a professional recommendation that tandem CPR be used when available, based on perception, performance, and physiological differences. This confirms professional guidelines. This study does not account for the anecdotally reported stress incited in CPR context; further research should examine this aspect.

Behavioral Ecology in the Northern Scorpion (Poster)

Synda Boumediene, Montana State University, Billings
Summit Parcell, Montana State University, Billings
Lea Henderson, Montana State University, Billings
Sarah Gallup, Montana State University, Billings
Colleen Tallon, Montana State University, Billings
Amanda Klein, Montana State University, Billings
James Barron, Department of Biological and Physical Sciences, Montana State University, Billings

The Northern Scorpion (*Paruroctonus boreus*) is a predatory arachnid. Although occurring at relatively high densities in local areas, conspecifics have seldom been observed sharing cover items. We investigated territoriality of scorpions by analyzing pairs of scorpions introduced into a habitat with a single, small cover item. We used mono- and bisexual pairs, similar and differently sized pairs, and pairs from the same or different populations. Scorpions were collected from two populations in south-central Montana. Results indicate that scorpions do interact over cover items, though not to the extent that we had anticipated. When scorpions were housed singly, they spent 80% of their time under cover. When size-matched pairs were offered a single cover item, up to 60% of the time

at least one scorpion was not under cover. Further, when differently-sized scorpions were paired, a similar result obtained with the larger scorpion excluding the smaller most often. Interestingly, these results all differed by population and sex. Scorpions from the naturally more-dense population excluded others more frequently than scorpions from the less-dense population. Additionally, males excluded other males more frequently than mixed-sex pairings excluded one sex or the other, or than females excluded other females. Finally, late in the experimental season (early Spring), there were six instances of cannibalism. In each case, females killed and consumed males. Though cannibalism has been previously documented in this genus, it has not been observed to be "seasonal" and has been attributed to size differential and not simply sex. In one of our cases, a smaller female killed and consumed a larger male. This pilot project provides several interesting questions to pursue regarding behavioral ecology in this species.

The Use of Trichostatin a to Rescue TRKA+ Neurons in a Mouse Model of Familial Dysautonomia (Poster)

Richard Buksch, Montana State University, Billings

Familial dysautonomia is a severe, recessive disease that devastates the peripheral nervous system, culminating in death of most patients by age 40. Studies have shown that there is a reduced number of both TrkA+ neurons and acetylation in familial dysautonomia patients and our mouse model of familial dysautonomia. Another feature of familial dysautonomia is a decrease in histone acetylation. This study evaluated the ability of the histone deacetylase inhibitor, Trichostatin A, to rescue the reduced number of TrkA+ neurons in the dorsal root ganglia in our mouse model of familial dysautonomia. Pregnant dams were treated with either 1mg/kg of Trichostatin A (experimental) or vehicle alone (control), at E8.5, E10.5, and E12.5, a time frame corresponding to neurogenesis in the mouse dorsal root ganglia. Immunohistochemistry was used to quantify the number of TrkA+ neurons at E17.5. Trichostatin A-treated knockout embryos (n=3) showed a significant increase in the number of TrkA+ neurons over vehicle only knockout embryos (n=3) (132.9% increase; $p<.00001$). Trichostatin A (1mg/kg) effectively rescues the number of TrkA+ neurons in our mouse model. Further studies will explore the cellular mechanisms via which histone deacetylase inhibition prevents neuronal cell death as well as the possible benefits of using these therapeutics for familial dysautonomia symptom management.

Oxidation of D-Glucose and D-Mannose (Poster)

Katelyn Duncan, University of Great Falls, Great Falls
Grace Ibsen, University of Great Falls, Great Falls
Chrissie Carpenter, Chemistry Department, University of Great Falls, Great Falls

The study of monosaccharides has been around and researched since the 1800's. In this experiment, D-glucose will undergo benchtop oxidation using nitric acid and heat to produce gluconic acid and glucaric acid. The same oxidation process will then be done using D-mannose. The resulting aldonic and aldaric acids of each compound will then be compared to determine if stereochemistry effects the ease at which an aldohexose can be oxidized at C-1 and C-6.

Riverine Carbon Cycling as a Function of Seasonality (Poster)

Christine Foreman, Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University, Bozeman
Emily Hultin, Center for Biofilm Engineering, Chemical and Biological Engineering, Montana State University, Bozeman
Juliana D'Andrilli, Department of Land Resources and Environmental Science, Montana State University, Bozeman

Montana has one of the most dynamic climate regimes in all of the United States, with seasonal changes spanning a large range of temperatures. In Montana, we depend on water originating from snow and glacial melt. These freshwater ecosystems are considered to be some of the most vulnerable to climate change on Earth. Glacially fed ecosystems are unique habitats for a vast array of life and geochemical processes, including carbon cycling. In order to study carbon cycling in environments vulnerable to change, an interdisciplinary approach including biogeochemical analyses of river DOM production and external allochthonous inputs is necessary to evaluate the impacts of climate change. The overarching hypothesis for this work is: Seasonal changes in Montana rivers will cause shifts in carbon cycling as ecosystems respond to changes in temperature. Unlike our initial hypothesis that the amount of sunlight and temperature would play a bigger role in what was happening, the time of the year was much more significant. In Big Sky OC levels in June for the sunny and canopy covered reaches were similar, 1.24 and 1.23 mg C/L, respectively; whereas at the end of July OC in the sunny reach was 0.42 mg C/Land the canopy cover reach was 0.955 mg C/L. The same trend is seen for the urban location in Bozeman. Cell abundance in the reaches followed similar trends, which were not solely based on temperature.

Analysis of BH31-1 Derivative's Effect on *Candida* Species (Poster)

Alexander Fryett, Montana State University, Billings
Joy Goffena, Department of Biological and Physical Sciences, Montana State University, Billings
Kurt A. Toenjes, Department of Biological and Physical Sciences, Montana State University, Billings

Candida species are the most common and arguably the most important causative agents of human fungal infections. Oropharyngeal, esophageal, vulvovaginal, and cutaneous candidiasis leads to significant morbidity while systemic infections in immunocompromised patients (patients with AIDS, tissue transplants, central venous catheters, or those undergoing chemotherapy) has a 35% mortality rate. During infection, it is essential that the dimorphic *Candida* species switch between different morphological states including transitions between budded or yeast-like cells and hyphal forms. The small molecule BH3I-1 has shown promising results at inhibiting hyphal formation in several *Candida* species. The goal of this study is to find a BH3I-1 derivative that inhibits hyphal formation in several Candida species at a lower minimum inhibitory concentration (MIC) than BH3I-1. A derivative with a low MIC that affects several *Candida* species may have a potential to be a broad-spectrum antifungal drug. The *Candida* species being tested against the BH3I-1 derivatives are: C. *albicans*, C. *glabrata*, C. *rugosa*, C. *krusei,* C. *tropicalis*, C. *lusitaniae*, C. *dubliniesis*, and C. *parapsilosis*. Currently, 36 BH3I-1 derivatives have been tested. Molecule 25 has an MIC about 4 times lower than BH3I-1 in *Candida* albicans and has also been shown to work in other *Candida* species at inhibiting hyphal formation. Other derivatives such as molecule #10 did not inhibit many of the tested *Candida* species, but showed a much lower MIC than molecule #25 in C. *rugosa*. Out of the 36 tested derivatives, molecule #25 has shown the promise for a broad-ranged antifungal drug.

Synthesis Of [CU(PDTC)L] Coordination Series (Poster)

Mohammadreza Heidari, Montana State University, Billings
Matt Queen, Department of Chemistry and Biochemistry, Montana State University, Billings
Tom Lewis, Montana State University, Billings
Hannah Kellinger, Montana State University, Billings
Ky Mickelson, Montana State University, Bozeman

Carbon tetrachloride (CCl_4) is a potential environmental contaminant in water, and soil. We are interested in studying potential CCl_4 environmental remediation technologies. Specifically we are interested in 2,6-pyridinedithiocarboxylic (PDTC) and the dechlorination properties of its copper based coordination compounds, $[Cu(PDTC)L]^X$. In the interest of creating better performing more soluble coordination compounds we seek to understand the link between coordination compound electronic structure and reactivity. With this ultimate goal in mind we present IR, UV-Vis and NMR evidence for the successful synthesis of a series of $[Cu(PDTC)_yL]^x$ coordination compounds. Here L=Cl, Br, I, CN, PPh_3 as well as the dimer species $[Cu(PDTC)_2]$.

Factors Influencing Owners' Willing to Pay for Veterinary Medicine Services for Pet Dogs: A Pilot Study (Poster)

Magdalena "Brice" Henning, University of Great Falls, Great Falls

The field of veterinary medicine has been changing dramatically over recent decades, as society changes its perspective on animals. Throughout human history, people have seen animals as a resource; now we are seeing them as companions or friends. A way to measure this changing perspective is to look at the amount of money that people are willing to spend on their pets. This study looked at dogs, in particular, and utilized a survey method to analyze factors that could influence people's willingness to pay for veterinary medicine services. Factor analyzed included the severity of the condition (life-saving aspect of surgery). likelihood of normal recovery, age of the dog, income level of owner, amount of owner's dog experience, and whether the owner was a health professional of any kind. Results: People were more willing to pay when the surgery was life-saving and when there was high likelihood of recovery. People were willing to pay more for younger dogs. Not surprisingly, there was a positive correlation between income level and owners' willingness to pay for veterinary services. Amount of experience with dogs had a varied effect on willingness to spend. It appeared that the owners' connection with health care professions also had an impact, although it did not reach statistical significance: those that were connected to the healthcare fields seemed more likely to pay. This study has implications for the practice of veterinary medicine today.

The Effects of Chronic Cortisol Exposure on the Innate Immune Response of Larval *Danio Rerio* (Poster)

Molly Herron, University of Great Falls, Great Falls
Judy Yau, Chemistry Department, Tufts University, Medford, MA
Ellen Hartig, MDI Biological Laboratory, Salisbury Cove, ME
James Coffman, MDI Biological Laboratory, Salisbury Cove, ME

Chronic stress is known to cause a variety of health complications linked to a dysregulated immune response, which could be an outcome of chronically elevated stress signaling mediated by the glucocorticoid steroid hormone cortisol. Previous research has shown that zebrafish embryos treated with cortisol for the first 5 days of development matured into pro-inflammatory adults with atypical regulation of immune-related genes (Hartig et al., 10.1242/bio.020065, 2016). The purpose of this study was to determine how chronic exposure to cortisol affects the innate immune response in larval zebrafish. To that end, the migration of neutrophils and macrophages were monitored following tail fin amputation. Results from this study provide evidence that cortisol-treated larvae had an increased number of macrophages near the amputation site, while the number of neutrophils was not significantly affected by cortisol exposure. These results suggest that chronically elevated glucocorticoid signaling specifically up-regulates the macrophage response to injury.

CBU_1932: A Hypothetical Dna-Binding Protein of the Q Fever Pathogen *Coxiella Burnetii* (Poster)

Benjamin V. Hickey, The University of Montana, Missoula
James M. Battisti, Division of Biological Sciences, The University of Montana, Missoula
Shaun G. Wachter, The University of Montana, Missoula
Michael F. Minnick, Division of Biological Sciences, The University of Montana, Missoula

Coxiella burnetii is an obligate intracellular bacterial pathogen that resides within a lysosome-like acidic compartment of the eukaryotic host cell and may cause acute and chronic human infections. Our recent transcriptome analysis of C. *burnetii* demonstrated that the CBU_1932 open reading frame displayed an exceptionally high transcript level at 11,481 transcripts per million (TPM), well above average transcript quantity for remaining ORFs in the genome. Due to it's high transcript level we hypothesize the corresponding protein may play an important role for *Coxiella*. Analysis of the CBU_1932 locus indicates that one of the adjacent ORFs, CBU_1933 is a hypothetical DNA binding protein. The protein encoded by CBU_1932 ORF consists of 66 amino acid residues with an unusually high percentage (42%) of residues being basic, including 20 lysines. Using BLAST algorithms we found CBU_1932 had no similarity with currently defined proteins, but has orthologues in other human intracellular pathogens such as *Legionella* and *Chlamydia*. Due to the high number of basic residues in CBU_1932, and linkage with a hypothetical DNA binding protein (CBU_1933), we hypothesize that CBU_1932 may also encode a protein involved with binding DNA or other negatively charged substrates. To address this hypothesis, we are in the process of cloning the 201-base pair CBU_1932 ORF into pMAL-c5x expression plasmid and analyzing the recombinant protein using DNA-binding protocols including electrophoretic mobility-shift assay EMSA. We are confident that characterization of this high-level transcript/highly basic protein will lead to a better understanding of the unique metabolism of *Coxiella* and other intracellular pathogens.

Determination Of Solubility Limits for Pdtc and Cu[Pdtc]Br (Poster)

Hannah Kellinger, Montana State University, Billings
Matt Queen, Department of Chemistry and Biochemistry, Montana State University, Billings
Tom Lewis, Montana State University, Billings
Angels Glassing, Montana State University, Billings
Ky Mickelson, Montana State University, Bozeman
Gabrielle Thelen, Montana State University, Billings

Carbon tetrachloride (CCl4) is an organic compound that once widely used as an industrial solvent, degreaser, and grain fumigant. Improper disposal and ground water solubility issues led to CCl4 being listed as a priority pollutant by the U.S. EPA. We are currently investigating the use of 2,6-pyridinedithiocarboxylic (PDTC) and its copper coordination compound $[Cu(PDTC)L]^x$ as a potential CCl4 environmental remediation technology. PDTC and Cu[PDTC]Cl have a very low solubility in water, which decreases the effectiveness of the molecule as a remediation technique. Using a ligated iron UV-Vis spectroscopy assay PDTC's solubility was determined to be 39 mM in a pH 7.6 (check this number) buffer. The solubility of Cu(PDTC)Br in pH 7.6 buffer was determined to be 50 mM via oversaturation UV-VIS assay. The results from both solubility studies were used to confirm a high throughput assay based on dynamic light scattering. The solubilities determined in this study will act as an initial benchmark for the comparison of future novel PDTC derivatives.

The Effect of the Cluffy Wedge on the Average Vertical Jump Height of Volleyball Athletes (Poster)

Ashley Klepec, Department of Biology, University of Great Falls
Madison Wilhelm, Department of Biology, University of Great Falls, Great Falls
Diane Lund, PhD, Department of Biology, University of Great Falls
James Clough, DPM, Foot and Ankle Clinic of Montana, Great Falls
Stephen Muir, PhD, Department of Mathematics, University of Great Falls, Great Falls

The aim of this study was to determine if placing the big toe in a dorsaflexed position affects the average vertical jump height of volleyball players and whether the grade of functional hallux limitus (FHL) limits its effectiveness. A polyurethane wedge (Cluffy Wedge) was placed under the big toe of 30 volleyball athletes. Two sets of three vertical test jumps were completed for each individual and t-tests of average jump heights showed no difference with or without the Cluffy Wedge. The subjects were then tested for FHL. Results showed slight significance in average jump heights for FHL grade 0 ($p= 0.1401$), while showing no significance in FHL grade 1 ($p= 0.6949$) and 2 ($p= 0.9045$). In conclusion, using a Cluffy Wedge to induce dorsiflexion of the big toe did not affect the average jump height of volleyball athletes and the FHL grade had no influence.

Zebrafish Stress Synapse (Poster)

Brynn Letang, University of Great Falls, Great Falls

Stress is a behavior characterized by uneasiness, nervousness, and fear that all organisms are faced with every day. Both environmental and chemical factors can trigger stress responses within the body. In this experiment, zebrafish (*Danio* species) will be stressed with environmental and chemical factors. Their cortisol levels, which is produced when stressed, will be tested by performing cortisol assays. The environmental factors that will be tested with light/dark apparatus that will investigate how environmental conditions stress the zebrafish. A beaker stressor will be used to investigate how the size of the environment effects stress on the zebrafish. Caffeine will be the chemical factor tested because it is addictive. Different concentrations of caffeine will be administered and the effects of these concentrations will use the cortisol assays. An ANOVA test will be done to quantify the data.

Endoplasmic Reticulum-Activated C/EBP Homologous Protein Mediates the Palmitate-Enriched Diet Induced Increase in the Lipogenic Expression in the Liver (Poster)

Gurdweep Marwarha, School of Medicine & Health Sciences, University of North Dakota, Grand Forks

Othman Ghribi, Department of Biomedical Sciences, School of Medicine & Health Sciences, University of North Dakota, Grand Forks

Non-alcoholic fatty liver disease (NAFLD) is a wide spectrum pathophysiological disorder characterized by insulin resistance, hepatic steatosis, and inflammation. Diets rich in saturated fat are known to evoke insulin resistance, ER stress, and de novo lipogenesis and thereby contribute to the pathogenic mechanisms involved in NAFLD. Palmitic acid (palmitate) is the most abundant saturated fatty acid in the diet and palmitate-enriched diets are known to cause NAFLD in a multitude of rodent models of NAFLD. Palmitate-enriched diets are known to induce steatosis by inducing the expression of genes involved in de novo lipogenesis. However, the signaling mechanisms and the downstream molecular mediators involved have not been elucidated. In this study, we explored the role of palmitate-induced ER stress and subsequent induction of C/EBP Homologous Protein (CHOP) expression in the modulation of expression and transcriptional activities of Liver X Receptor alpha (LXRα) and Sterol Response Element Binding Protein 1c (SREBP1c), two indispensable transcription factors and master regulators of genes involved in de novo lipogenesis. We demonstrate, in exogenous palmitate-treated HepG2 cells and in the livers of palmitate-enriched diet-fed mice, that palmitate evokes ER stress leading to the induction of CHOP expression. We further show that CHOP mediates the up-regulation in expression levels and transcriptional activities of LXRα and SREBP1c. Our study identifies a unique ER stress-CHOP-LXRα/SREBP1c signaling pathway that mediates palmitate-induced up-regulation of lipogenic gene expression in the liver that may play a critical role in the etiopathogenesis of NAFLD.

Modeling the Distribution of Pollutants for a Mine (Poster)

Mark Melton, University of Great Falls, Great Falls

The institution of new mining facilities is a constant threat to environmental persistence and abundance. This issue can be minimalized with greater insight into how pollutants spread. Understanding the dispersal of pollutants allows cleanup efforts to be directed in an extremely efficient manner. To determine the spread of pollutants, the Belt Creek Drainage which has several mining facilities was chosen to be tested for specifically Arsenic, Selenium, and Lead. Using ICP (Inductively Coupled Plasma) the concentrations of each pollutant was determined at various points along the drainage system. The data retrieved was then synthesized in GIS (Geographic Information Systems) to create a gradient showing the concentration changes across distance within the river system. This type of analysis is extremely applicable to understanding how and where pollutants can be predicted to accumulate and can enhance the effectiveness of pollutant cleanup efforts.

Developing a Yeast Model of Amyotrophic Lateral Sclerosis Involving the SOD1 Gene (Poster)

Kyler Pawlowski, Montana State University, Billings
Joy Goffena, Department of Biological and Physical Sciences, Montana State University, Billings
David K. Butler, Montana State University, Billings

Amyotrophic lateral sclerosis (ALS), one of the most common neuromuscular diseases in the world, is an unremittingly progressive disease that degenerates motor neurons in the brain and spinal cord. Roughly 10% of ALS cases are considered familial and can result from mutations in more than dozen different genes. The most common mutations in familial ALS occur in the SOD1 gene. SOD1 encodes a copper-zinc superoxide dismutase that detoxifies oxygen free radicals. To date, approximately 140 mutations in SOD1 (many of which are missense) have been linked to familial ALS. Evidence suggests that these mutations induce SOD1 protein misfolding and aggregation into cytotoxic structures. We are developing a yeast model of ALS based on the expression of mutant human SOD1 proteins. Such a yeast system will permit high throughput genetic screens to identify genes that enhance or suppress the toxic phenotypes associated with mutant SOD1 expression (thereby identifying critical supporting or suppressing pathways), as well as chemical screens to identify compounds that inhibit mutant SOD1 toxicity.

Proximate Analysisof Fish Feed (Poster)

Alexis Rickets, University of Great Falls, Great Falls
John Bayulut, Chemistry Department, University of Great Falls, Great Falls

An aquaponic system shows evidence of increasing economic efficiency and environmental sustainability. An efficient aquaponic system is heavily dependent on the quality of aquatic life in it. In order to ensure the quality of the aquatic life, the quality of its feed must be ensured as well. This research uses proximate analysis to analyze fish feed in terms of percent moisture, fat content, crude fiber extraction and crude protein extraction and correlate these with fish body composition as well.

How AQP3B Influences Convergent Extension Through Noncanonical WNT Signaling (Poster)

Kaitlyn See, Montana State University, Bozeman
Christa Merzdorf, Department of Cell Biology and Neuroscience, Montana State University, Bozeman
Jennifer Forecki, Department of Cell Biology and Neuroscience, Montana State University, Bozeman

Aquaporin-3b, Aqp3b, is an aquaglyceroporin, a membrane water channel that is present during gastrulation and various other stages of development. Gastrulation organizes cells, via convergent extension, into germ layers, which will later form different body tissues. During gastrulation, cells fold into the embryo, then merge by convergent extension to form the long body axis. These cell movements are regulated by noncanonical Wnt signaling, an intercellular signaling pathway that controls the migration and polarity of tissues. When Aqp3b is inhibited using a morpholino oligonucleotide (MO), convergent extension does not occur properly, suggesting a link between Aqp3b and noncanonical Wnt signaling. To assay these defects, we use the Keller tissue explanting method to observe convergent extension. Our goal is to determine which parts of the Wnt signaling pathway are influenced by Aqp3b. We conducted rescue experiments by inhibiting Aqp3b and injecting an RNA or DNA construct of several proteins involved in Wnt signaling. Successful rescue with Dvl1ΔDix and Dvl2ΔDix constructs indicated that Aqp3b is involved in noncanonical Wnt signaling, since DvlΔDix acts in all noncanonical Wnt signaling. Further, Aqp3b acts through the Wnt/Ca2+ subpathway, indicated by rescue by PKC, and through a branch of the Wnt/PCP pathway, indicated by successful rescue with RhoA but not with Rac1. Aqp3b does not directly affect the Wnt/Ror2 pathway. In conclusion, I have demonstrated that the ability of Aqp3b to influence convergent extension is dependent on noncanonical Wnt signaling, specifically the Wnt/Ca2+ pathway and the RhoA branch of Wnt/PCP pathway. I am collecting additional data to ensure statistical significance.

Characteristics of the Effect of Exogenous Camp on C. Albicans Morphogenesis in Strains Lacking NRG1P, RFG1P, or TUP1P (Poster)

Brandon Van Tassel, Montana State University, Billings
Joy Goffena, Department of Biological and Physical Sciences, Montana State University, Billings
Kurt A. Toenjes, Department of Biological and Physical Sciences, Montana State University, Billings

The opportunistic human pathogen *Candida albicans* causes both superficial and life threatening systemic infections and is a leading cause of fungal disease in immunocompromised individuals such as those with AIDS. C. *albicans* can grow in different cell shapes, also known as morphologies, including yeast-like cells and a variety of filamentous forms, such as true hyphae and pseudohyphae. Yeast, hyphae and pseudohyphae, have been observed at the sites of *Candida* infection and there is strong evidence that morphogenesis, the transition between yeast and filamentous growth forms, is essential for its virulence. Many studies have implicated the second messenger molecule cAMP in the regulation of morphogenesis due to its role in activating filamentation. Our lab and others have previously characterized the impact of the negative regulators, Nrg1, Rfg1, and Tup1 on the expression of HWP1, a hyphal specific gene. The goal of this project is to characterize whether the addition of exogenous cAMP will increase the expression of HWP1 in the absence of each of the negative regulators as well as test a small molecule derivative of BH3I's effects in conjunction with the exogenous cAMP. This will help us better understand the signal transduction cascade that controls morphogenesis in *C. albicans*.

Does the Misregulation of Codon-Biased Genes in the Anterior Pituitary Contribute to Familial Dysautonomia? (Poster)

Joseph Walters, Biological and Physical Sciences, Montana State University - Billings, Billings
Joy Goffena, Biological and Physical Sciences, Montana State University - Billings, Billings
Shelby Staples, Biological and Physical Sciences, Montana State University - Billings, Billings
Lynn George, Biological and Physical Sciences, Montana State University - Billings, Billings

Familial Dysautonomia (FD) is a devastating neurodevelopmental and neurodegenerative childhood disease characterized by a diminished number of autonomic neurons. FD children suffer from a multitude of autonomic symptoms including cardiovascular instability, gastrointestinal incoordination, and respiratory dysfunction. FD patients also exhibit an abnormal autonomic stress response, tend to be small in stature, and have difficulty gaining and maintaining weight. FD results from a mutation in the IKBKAP gene and diminished levels of the corresponding protein IKAP, a scaffold that assembles the multi-subunit complex, Elongator. Elongator functions in the modification of tRNAs that mediate translation of AA- and AG-ending codons. IKAP is expressed throughout the autonomic nervous system and historically FD symptoms have been attributed to autonomic dysfunction. Here we show that IKAP is also robustly expressed in the pituitary gland, both during development and in the adult. We hypothesize that many FD symptoms may actually result from aberrant pituitary regulation of the autonomic nervous system. To test this hypothesis we are currently generating a conditional knockout mouse where Ikbkap will be selectively ablated in the anterior pituitary. While waiting for our mouse model, we have been optimizing techniques for quantifying pituitary specific genes that are likely candidates for Elongator regulation based on their content of AA- and AG-ending codons.

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