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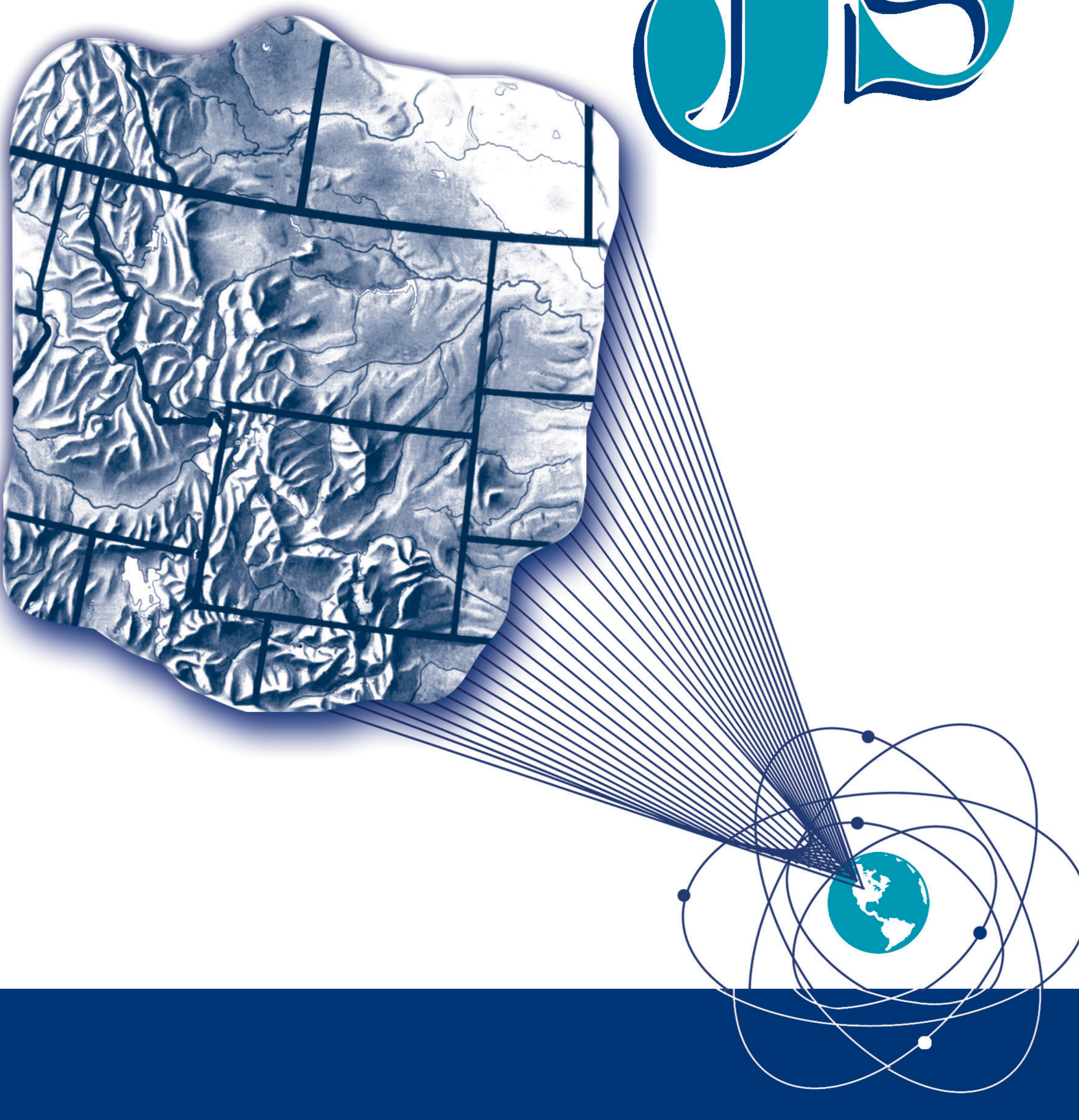

Intermountain Journal of Sciences

The Intermountain Journal of Sciences is a regional peer-reviewed journal that encourages scientists, educators and students to submit their research, management applications, or view-points concerning the sciences applicable to the intermountain region. Original manuscripts dealing with biological, environmental engineering, mathematical, molecular-cellular, pharmaceutical, physical and social sciences are welcome.

Co-sponsors/publishers include the Montana Academy of Sciences, the Montana Chapter of The Wildlife Society, and the Montana Chapter of The American Fisheries Society. This journal offers peer review and an opportunity to publish papers presented at annual meetings of the co-sponsor organizations. It is the intent of the governing bodies of the co-sponsor organizations that this journal replace printed proceedings of the respective annual meetings. Therefore, it is the policy of the editorial board that presenters at annual meetings of the co-sponsors be given priority in allocation of space and time of publication, although submission of other manuscripts for review and publication without regard to membership is encouraged.

Initial funding was provided by the co-sponsor organizations. Long-term funding will be derived from page charges assessed authors, sponsoring organizations or agencies at $60 per printed page upon acceptance of each manuscript and from annual subscriptions: student $6; regular member $15; patron member $25; overseas member $25; library $25; life member $150; and, sustaining subscriber $2,500.

The intent of the co-sponsors and editorial board is that ***The Intermountain Journal of Sciences*** be expanded to a quarterly journal. Achieving that objective depends upon numbers of acceptable manuscripts received and available funding. It also is the intent of the editorial board that contributing authors be assured of publication within 12 months of acceptance of their manuscript by the managing editor.

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 sponsoring organizations. 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 liaison for layout and printing. Associate editors include but are not limited to the section vice presidents of The Montana Academy of Sciences. Referees are selected on the basis of their field and specific area of knowledge and expertise.

Referees and associate editors judge submitted manuscripts on originality, technical accuracy, interpretation and contribution to the scientific literature. Format and style generally follow the *Guidelines for Manuscripts Submitted to the Intermountain Journal of Sciences, Dusek 1995, revised 2007.** Organization may vary to accommodate the content of the article, although the text is expected to elucidate application of results.

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Balance 01/01/11		**$1,462.37**
Income:		
	Subscriptions:	
	Regular Member	$90.00
	Library Subscriptions	$275.00
	International Member	$25.00
	Subscriptions Total	**$390.00**
	Page Charges	$6,852.07
	Reprints	$760.98
	Back Issue Sales	$10.00
	Total Income	**$8,013.05**
Expenses:		
	Design and Printing	$6,456.17
	Postage	$316.16
	P. O. Box Rent	$96.00
	Administrative and Bank Fees	$194.10
	Reprints and Layout	250.00
	Website Maintenance	318.75
	Total Expenses	**$7,631.18**
Balance 12/31/11		**$1,844.24**

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 this journal, 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). 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 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 coy 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 required for each manuscript. The two other reviewers are instructed to return the manuscript and their comments to the Associate Editor, who completes and returns to the EIC a blue "Cover Form" and all manuscripts and reviewer comments plus a recommendation for publication, with or without revisions, or rejection of the manuscript. This initial review process is limited to 30 days.

The EIC reviews the recommendation and all comments. The EIC then 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, four copies if further review is required, or one hard copy plus the computer disk if only minor revision or formatting is necessary. The revised manuscript shall be returned to the EIC within 14 days of the 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 new manuscript. The new 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 Chairman of the Editorial Board of IJS, who will serve as the EIC for that manuscript.

Abstracts

Only abstracts 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 Gary Dusek, the EIC (gnpdusek@msn.com), on or before November 1. Each abstract shall be reviewed by the EIC to assure proper grammar, compliance with IJS "Guidelines for Abstracts Only" and for assignment to the appropriate discipline section. All abstracts will be published in the December issue only.

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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Survival and Movement of Adult Rainbow Trout During Winter and Spring in the Henrys Fork of the Snake River

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Abstract

Discharge downstream from Island Park Dam on the Henrys Fork of the Snake River in Idaho is reduced each winter to facilitate storage of irrigation water. The effect this has on survival and movement of adult rainbow trout (*Oncorhynchus mykiss*) in this area is unknown. Additionally, fish movement during the spring has not been evaluated but may affect population estimates conducted in the tailwater monitoring area downstream from Island Park Dam prior to opening of fishing season. Therefore, we used radio telemetry to evaluate winter survival and movement of 61 adult rainbow trout in the Henrys Fork downstream from Island Park Dam under low and extremely low early winter flow conditions. Spring movement was also evaluated to asses whether the population estimates conducted in the monitoring area each spring represent fish from downstream adjacent reaches of the river, and how emigration between mark and recapture periods may affect the population estimate. Survival of radio-tagged trout was nearly 100 percent during early winter under both low and extremely low flow conditions and winter movement did not differ between the two years. Few radio-tagged rainbow trout from downriver were present in the monitoring reach during the time when the population estimate is normally conducted, indicating that large fluctuations in fish numbers in downstream reaches would likely be undetected based on population estimates conducted in the monitoring area. To remedy this, establishing a separate, regular population monitoring area in downstream reaches is recommended. We determined emigration from the monitoring reach between mark and recapture to have a minimal effect on the population estimate. However, we noted that all radio-tagged trout moving out of the monitoring reach during May moved into a short section of river between the monitoring reach and Island Park Dam, presumably to spawn. Therefore, emigration could be largely eliminated by extending the monitoring reach upstream to the dam.

Key words: telemetry, movement, survival, low flow, winter, adult rainbow trout

Introduction

The Henrys Fork of the Snake River contains a world-renowned wild rainbow trout (*Oncorhynchus mykiss*) fishery from Island Park Dam downstream to Mesa Falls. Island Park Dam blocks fish passage and stores sediment that is occasionally released en mass (Van Kirk and Gamblin 2000), impacting spawning habitat (HabiTech 1994) and winter concealment habitat for age-0 trout (Gregory 2000). However, the most recurring impact to the fishery is the reduced winter flows that facilitate storage of irrigation water in Island Park Reservoir (Benjamin and Van Kirk 1999, Gregory 2000, Mitro et al. 2003). The number of juvenile rainbow trout that survive their first winter is directly related to the magnitude of late winter flows from Island Park Dam (Mitro et al. 2003, Garren et al. 2004), but the effect of low winter flows on survival of adult trout in the Henrys Fork is unknown. Winter on the Henrys Fork has been defined as the period during which juvenile rainbow trout adopt concealment behavior (Smith and Griffith 1994). In our study area, this typically occurs from October to May (J. Gregory unpublished data). However, to parse actual winter movements from spawning related movement, we defined winter as that period from October through January.

In addition to the normally occurring low winter flows from Island Park Dam (~ 5.7 m^3/s [200 cfs]), occasional dam repairs and past chemical treatments (see Van Kirk and Gamblin 2000) of the reservoir pool have necessitated complete termination of flow from Island Park Dam. When this occurs, the Henrys Fork is nearly dewatered for ~ 600 m from Island Park Dam to the Buffalo River, a spring-fed tributary that has a winter flow of ~ 5.7 m^3/s (200 cfs). During these periods, the already altered low flow through much of the Henrys Fork is further reduced. These extremely low flow conditions only occur during early winter (Nov and Dec), when flows apparently do not regulate juvenile trout numbers (Mitro et al. 2003, Garren et al. 2004). However, the effect of extremely low flows on adult trout survival is unknown.

Movement of adult rainbow trout in relation to low and extremely low winter flows and winter habitat availability in the Henrys Fork has not been previously studied. Winter concealment behavior has been observed in adult rainbow trout (Meyer and Gregory 2000) and enhances survival of juvenile rainbow trout in the Henrys Fork (Smith and Griffith 1994, Meyer and Griffith 1997a, Mitro and Zale 2002). In fact, where cobble-boulder concealment habitat is absent, juvenile trout emigrate (Meyer and Griffith 1997a) or die (Smith and Griffith 1994) as juvenile trout numbers decline in areas lacking this habitat (Griffith and Smith 1995, Mitro and Zale 2002). Because Box Canyon contains the majority of the cobble-boulder habitat in the study area, most juvenile trout that survive their first winter do so in that stream section (Mitro and Zale 2002). If cobble-boulder concealment habitat is important for adult trout in the Henrys Fork, we would expect fall/early winter movements of adult trout into Box Canyon, but it is unknown if such movements occur.

Rainbow trout spawning habitat in the study area is most abundant within the Box Canyon reach, which creates an interesting situation relative to springtime fish population monitoring conducted in this reach. The Idaho Department of Fish and Game (IDFG) conducts annual mark-recapture population estimates within Box Canyon before the fishing season opens in late May (Garren et al. 2008), which coincides with the rainbow trout spawning period. The estimates produced are thought to reflect population trends in Box Canyon and in downriver adjacent reaches of the Henrys Fork. However, how many rainbow trout from downstream reaches may be represented in those estimates because of movement to Box Canyon for either winter habitat, spawning, or other purposes, is unknown.

Emigration, immigration, or mortality of rainbow trout during the springtime population estimate violates the assumption of a closed population. To minimize departure from a closed population, the mark and recapture events were typically separated by 7 days. We believe this relatively short time interval allows fish to redistribute themselves within the monitoring area, while avoiding excessive immigration and emigration (D. Garren, IDFG, personal communication). However, the extent of immigration and emigration within this time period in the monitoring area was unknown. Although mortality within the monitoring area during the sampling period was unknown, spawning-related mortality can be high for rainbow trout (Hartman et al. 1962). High mortality rates during spawning may again violate the assumptions of a closed population, i.e., no deaths occurred within the sampling period.

The objectives of this study were to 1) evaluate survival and movement of adult rainbow trout during typical and extremely low winter flows, 2) assess the extent to which rainbow trout from downstream reaches move into Box Canyon during the winter or spring and are represented in the population estimate, and 3) assess how rainbow trout movement and mortality between the mark and recapture periods may affect springtime population estimates.

Understanding winter movement

and mortality of adult rainbow trout in the Henrys Fork will help managers understand whether flow regimes devised to enhance survival of juvenile rainbow trout (Mitro et al. 2003) affect adult rainbow trout. Springtime movement patterns of adult trout will reveal the extent to which population trends observed in the monitoring area may represent fish from other reaches of the river. Furthermore, quantifying movement and mortality during the time when population sampling is conducted will help managers understand the validity and variability of population estimates.

Study Area

The Caldera Section of the Henrys Fork is about 47 km long and is located in eastern Idaho within the Island Park Caldera (Van Kirk and Benjamin 2000). Our study area was the upstream portion of that section and extended from Island Park Dam to the downstream boundary of Harriman State Park, a distance of 21.4 km (Fig 1).

The river has a higher gradient, and has more available spawning habitat in the upstream reach (Box Canyon, 0.5%) and both gradient and availability of

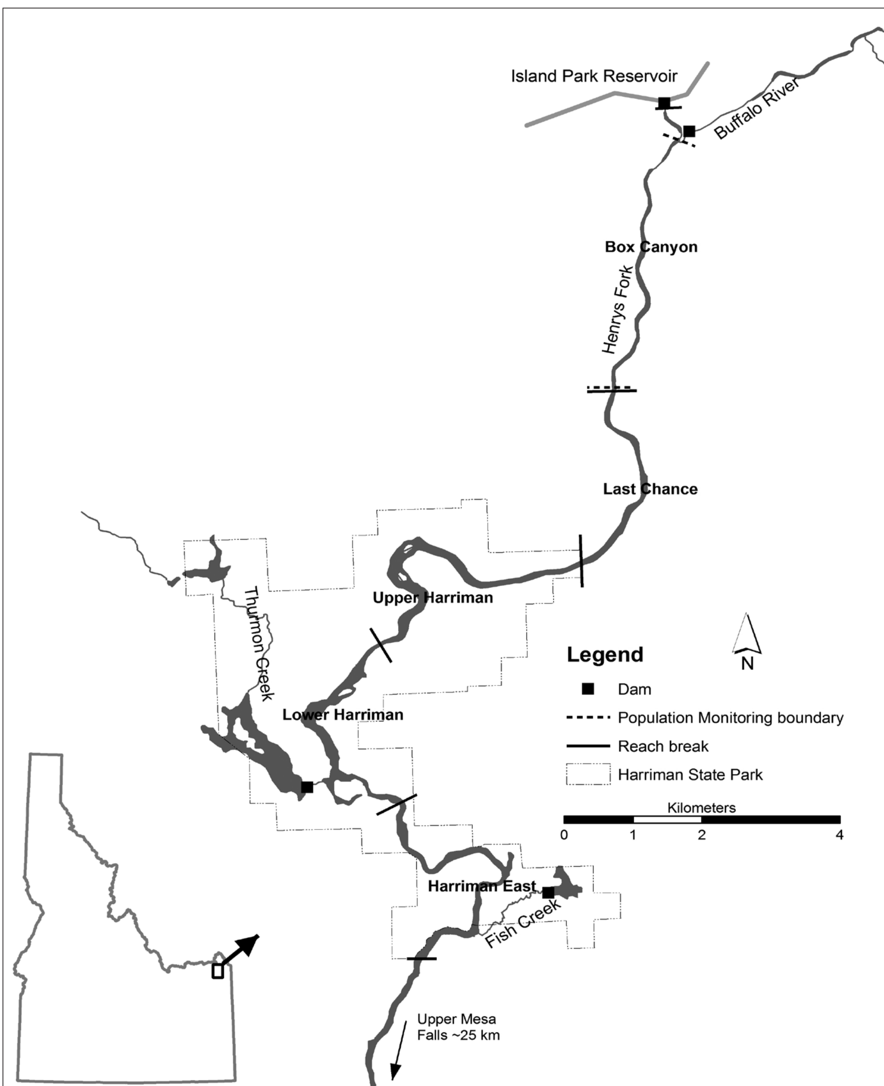

Figure 1. Location of the Caldera Section of the Henrys Fork in eastern Idaho and the various reaches within the study area.

spawning habitat decrease incrementally in downstream reaches to Harriman East, which is characterized with a low gradient (0.1%) and fine substrates.

The study area contains four tributaries that contain spawning habitat: the Buffalo River, along with Blue Spring, Thurmon, and Fish Creeks. The Buffalo River is blocked by a small hydroelectric project dam, about 200 m upstream from its mouth, which adult rainbow trout can pass by means of a fish ladder (Gregory 2000). Rainbow trout spawning habitat is present in the Buffalo River upstream from the dam, but is limited in Blue Spring Creek and the accessible portions of Thurmon and Fish creeks (Gregory 1998).

The IDFG conducts population estimates nearly every May in a monitoring area within Box Canyon. The monitoring area begins at the mouth of the Buffalo River, 0.6 km downstream from Island Park Dam, and extends 3.7 km downstream to the bottom of a riffle near the mouth of the canyon (Garren et al. 2008; Fig. 1). Population estimates (n = 10) from 1995 to 2006 of rainbow trout ≥ 150 mm have a mean density of 1747 trout/km and have ranged from 1018 to 3471 trout/km or about a total of 3767 to 12,841 rainbow trout within the monitoring area in Box Canyon (Log-likelihood method; Garren et al. 2008). Brook trout (*Salvelinus fontinalis*) are present but rare and mountain whitefish (*Prosopium williamsoni*) are plentiful. The entire study area is managed with catch-and-release regulations for rainbow trout and is closed to fishing from December through late May.

Methods and Materials

Mortality and movement of rainbow trout in the Henrys Fork was evaluated by implanting radio transmitters into 61 adult rainbow trout during the fall, and tracking their movements through the following spring. The Henrys Fork in the study area was divided into five reaches (Fig. 1) of analogous habitat types (see Mitro and Zale 2002): Box Canyon (4.9 km), Last Chance (3.3 km), Upper Harriman (4.8 km), Lower Harriman (3.7 km) and Harriman East (4.7 km). In late October of water year 2004, we collected 11 rainbow trout from the Last Chance/ Upper Harriman Reach and 11 rainbow trout from the Lower Harriman Reach by drift-boat electrofishing. Trout were radio tagged and released at the downstream ends of the Upper and Lower Harriman reaches, respectively. The following day, an additional 18 rainbow trout were collected immediately downstream from Island Park Dam by netting during a salvage operation, when flows from Island Park Dam were terminated to facilitate repairs to the outlet works. These fish were radio-tagged and released where water from the Buffalo River Hydroelectric Project enters the Henrys Fork, just upstream from the mouth of the Buffalo River. During November of water year 2005, an additional 21 fish were captured by hook-and-line throughout Box Canyon and were radio tagged and released at their capture locations.

Radio transmitters were surgically implanted using a shielded-needle technique similar to Winter (1996) and Swanberg et al. (1999). Transmitters (Advanced Telemetry Systems model F1815, 3 volt, 12 mm diameter x 36 mm long, 7 g, 150 MHz) had a 30.5 cm trailing whip antenna and a mortality switch that was activated when they remained motionless for 24 hrs. Transmitters were programmed to turn on for 12 hrs every 4 days. Radio transmitters and surgical instruments were sanitized prior to each surgery with either a betadine solution or isopropyl alcohol. Prior to surgery, fish were anesthetized with clove oil (Anderson et al. 1997) at a concentration of 60 mg/l, and were weighed and measured. Length of all radio-tagged trout ranged between 340 and 600 mm and weighed between 0.45 and 2.70 kg. Therefore, transmitter weight was always less than 2 percent of the fish's body weight as suggested by Winter (1996). Surgeries were conducted by placing the fish upside down on a wooden trough-shaped operating table that was submerged in the above anesthetic solution. An incision (~15 mm long) was made anterior to the pelvic girdle and slightly removed from the fish's mid-ventral line. An 18-gauge needle was then pushed through the body wall slightly posterior and laterally from the incision. The transmitter antenna was inserted into the incision and then pushed through the needle; the needle was then removed leaving the antenna extending through the hole made by the needle. The transmitter was then placed inside the body cavity and moved posterior by pulling gently on the antenna. The incision was closed with stainless steel staples (Swanberg et al. 1999) and/or sutures. Fish were observed until the effects of the anesthetic had subsided, and were then released.

Radio-tagged fish were relocated about once every month from the time of tagging until early March. Thereafter, fish were relocated every 4 days until the end of May, and then twice a month throughout the summer and fall. Tracking ended in mid-July 2005. Fish were tracked with an Advanced Telemetry Systems R2100 receiver while either floating the river or following it along the bank. Tracking began at Island Park Dam and proceeded downstream through Lower Harriman and sometimes through Harriman East. Fish locations were recorded relative to Global Positioning System (GPS) reference points along the river. GPS reference points were spaced about 400 m apart in Box Canyon with this spacing increasing to 700 m downstream from Box Canyon. When fish were located near reach breaks or the monitoring area boundaries, care was taken to determine which reach they were in and whether or not they were within the monitoring area. When a mortality signal was encountered the fish was recorded as deceased and the tag was recovered, if possible. Fish that died within four weeks of tag implantation were assumed to be the result of handling and surgery.

Results

Survival of radio-tagged trout during the winter was high during both years.

All fish radio-tagged in Box Canyon survived the early winter period (Nov and Dec) both during extremely low flows (water year 2004) and during the same period of low flows the following water year (Fig. 2). Additionally, late-winter (Jan - Mar) survival of radio-tagged fish was 100 percent for fish that experienced extremely low early winter flows (water year 2004) and was > 80 percent for fish that experienced low early winter flows the following year. Winter survival of radio-tagged fish downstream from Box Canyon was also high; two fish were considered tagging mortalities and the remaining 20 survived through mid-March (Fig. 2).

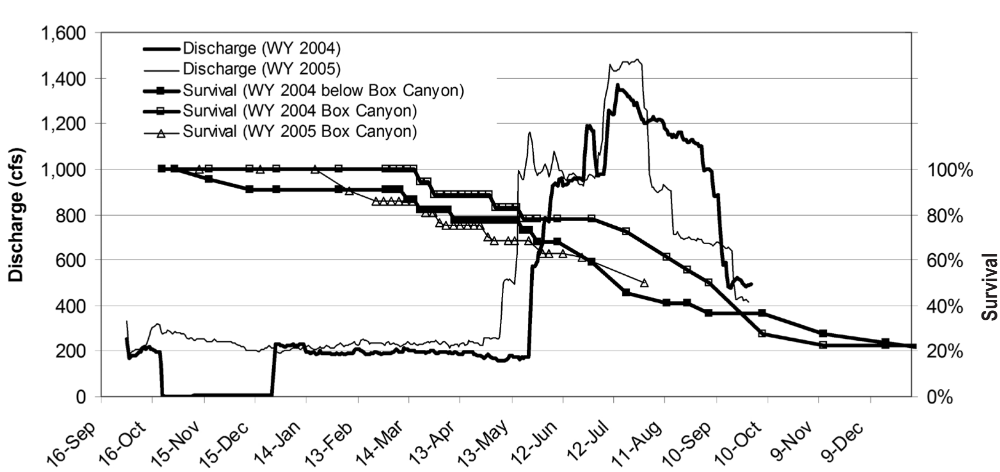

Figure 2. Survival of radio-tagged rainbow trout collected downstream from Box Canyon during water year (WY) 2004 and in Box Canyon during (WY) 2004 and 2005 relative to discharge at Island Park Dam during (WY) 2004 and 2005.

Aside from redistribution movements immediately after tagging, trout movement among fish tagged in Box Canyon was similar during the extremely low flow period and during a corresponding time period the following year. Movements between tracking periods for radio-tagged trout during this period (Nov and Dec) averaged about 0.5 km and ranged from 0 to 2.9 km. Redistribution movements following tagging differed between years. In water year 2004, salvaged fish redistributed themselves rather quickly following tagging. These fish dispersed downstream through Box Canyon within one month (average movement 1.2 km, range 0 to 4.4 km) where they spent the winter, and they did not immediately return to their capture location when water was again released from the dam on 26 December. In water year 2005, a similar redistribution movement was not observed, but rather most fish remained near their capture location (average movement 0.5 km, range 0.0-5.0 km).

Fish tagged in the upper and lower Harriman reaches moved back upstream into the areas from which they were captured within one month, and 15 of 20 were never observed downstream from their release location. Most of the radio-tagged trout from the Last Chance and Harriman reaches did not migrate to Box Canyon before February. The exception to this was one fish that spent the winter immediately downstream from Box Canyon and was located in the lower end of Box Canyon during a single tracking period in December.

Radio-tagged trout from downstream reaches made apparent spawning migrations into the population monitoring area from February through May (Fig. 3), but because movements were staggered and some of those fish moved back out of the monitoring area before May, not all of those fish would have been represented in a population estimate. Throughout this period, radio-tagged fish of all size classes tagged moved to the monitoring area from the Last Chance/

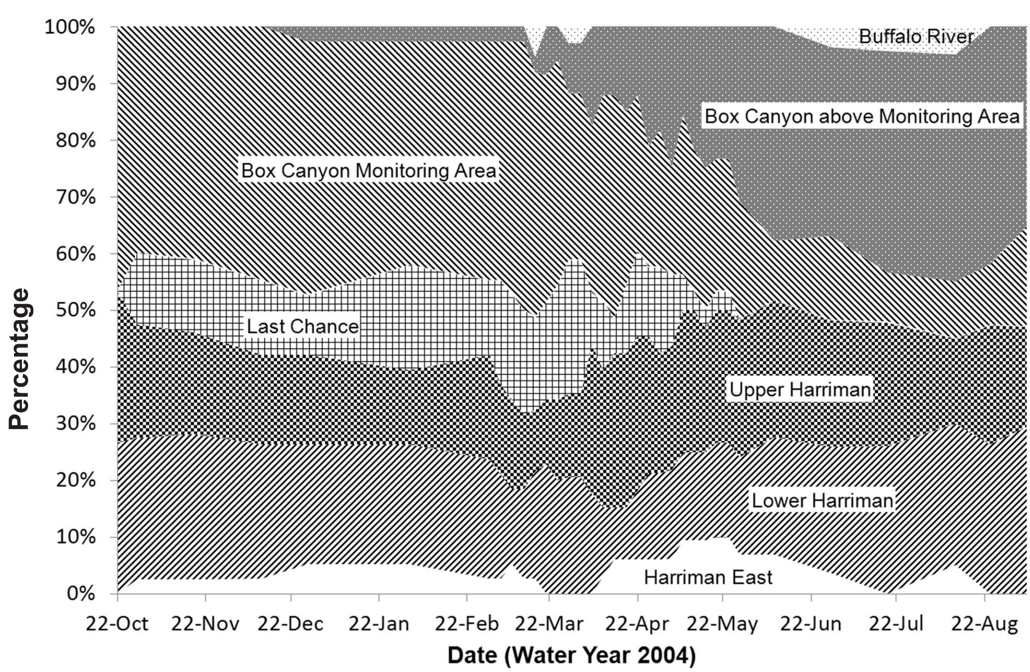

Figure 3. Percentage of radio-tagged adult rainbow trout present in each section of the study area throughout water year 2004.

Upper Harriman reaches (2 of 10) and the Lower Harriman Reach (4 of 10). However, during any given 8-day period in May 2004, during which a population estimate could have been conducted, 6 to 12 percent of fish radio-tagged downstream from Box Canyon were present in the monitoring area. Most of the radio-tagged fish that survived through May returned to their pre-spawning location by June. Most of the radio-tagged fish (11 of 16) that were salvaged immediately below Island Park Dam during water year 2004, returned to their pre-capture location during the apparent spawning period.

All of the fish tagged in Box Canyon during water year 2005 were within the population monitoring area during the first tracking period in May (Fig. 4). During any given 8-day period of May, 8 to 23 percent of those fish moved upstream, out of the population monitoring area, and none moved downstream out of the monitoring area. All of these trout were > 400 mm. No radio-tagged rainbow trout died in the monitoring area during May. However, one radio-tagged trout that had moved upstream out of the monitoring area in May then died 8-12 days later in its new location.

Discussion

Radio-tagged adult rainbow trout winter survival and movement was similar during low and extremely low flow years. Winter survival of radio-tagged rainbow trout in our study was nearly 100 percent, suggesting that even extremely low winter flows do not limit adult trout numbers in the study area at contemporaneous densities (1197 trout ≥ 150 mm/km in the Box Canyon monitoring area; see Garren et al. 2008). Therefore, adult trout survival is not affected by the Island Park Dam current operating procedure of releasing less water in early winter in exchange for more water later in the winter, which increases survival of juvenile rainbow trout (Mitro et al. 2003). One caveat to this assertion is that survival could be negatively impacted if air temperatures drop to the point that ice formation occurs. While shelf ice provides concealment habitat for juvenile

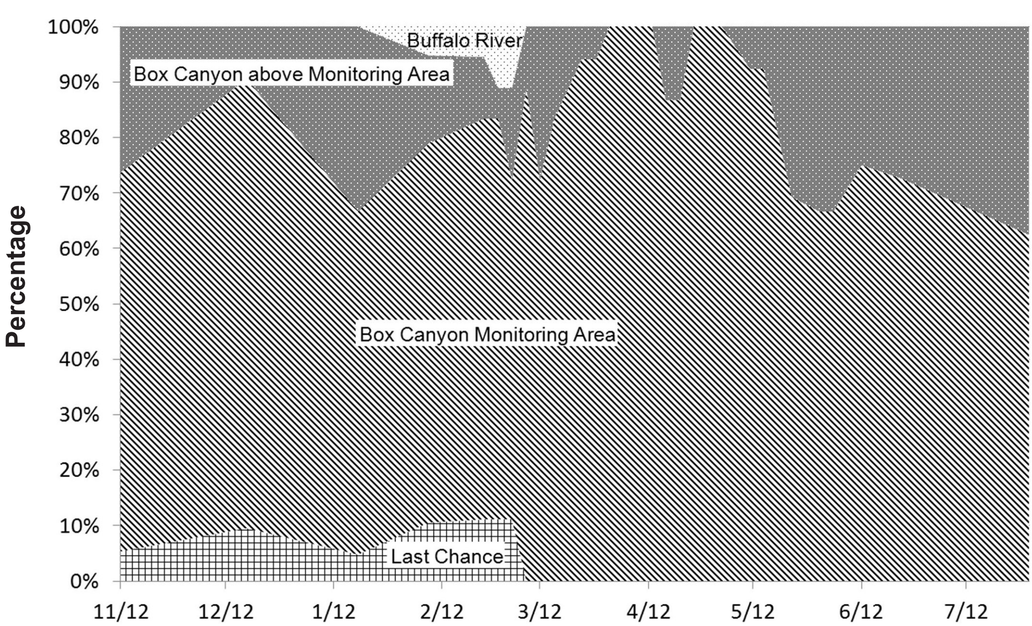

Figure 4. Percentage of radio-tagged adult rainbow trout present in each section of the study area throughout water year 2005.

and adult trout and can cause them to be less reliant on other types of concealment cover (Gregory and Griffith 1996, Jakober et al. 1998), frazil ice (Simpkins et al. 2000) and anchor ice (Chisholm et al. 1987, Jakober et al. 1998, Lindstrom and Hubert 2004) can reduce habitat suitability and result in emigration of fish which may increase mortality. Water released from the hypolimnion of Island Park Reservoir and tributary inflows from the spring-fed Buffalo River typically keep Box Canyon free of ice. However, the resulting open water facilitates formation of frazil ice and anchor ice in downstream reaches (Last Chance and Harriman) of the study area. This frazil ice can adhere to macrophytes causing rapid macrophyte sloughing (Griffith and Smith 1995, Simpkins et al. 2000) effectively reducing concealment habitat for juvenile and likely adult trout (Heggenes et al. 1993) at a time when conditions for trout movement are most severe.

Our observations that survival of adult rainbow trout in the Henrys Fork does not appear to be affected by low winter flows is consistent with those of Sutton et al. (2000) who found no clear demonstrable effect of low winter flows on health of rainbow trout in the San Juan River downstream from Navajo Dam. Furthermore, McKinney et al. (2001) suggested that in the Colorado River downstream from Glen Canyon Dam, small rainbow trout were more strongly influenced by physical factors, such as winter flow, than were large trout. This also seems to be the case in our study area (Mitro et al. 2003, Garren et al. 2004, this study). Given this, we suggest that consideration of juvenile rainbow trout needs may be more important than the needs of adult rainbow trout in formulating winter flow regimes below hypolimnetic release dams. However, additional research is needed to assess this hypothesis in other areas and to determine how it may change in areas further downstream from dams, where stream habitat conditions may be more affected by ice.

Average winter movements for radio-tagged trout in Box Canyon between tracking periods were 0.7 km. These movements are much larger than winter movements observed for rainbow trout (Gido, et al. 2000) and cutthroat trout (*Oncorhynchus clarkii*) (Jakober et al. 1998) in other areas. The stationing of our reference GPS points along the stream could have caused movements to appear magnified. However, the studies outlined above reported a general lack of winter movement for trout, which is contrary to what we observed. Radio-tagged trout in this study may have moved more often because of the relatively moderate winter water temperatures resulting from hypolimnetic releases from Island Park Dam and inflow from the spring-fed Buffalo River.

Radio-tagged fish in our study did not make late-fall or winter migrations among study reaches. Trout migration to wintering areas has been observed in other rivers (Meka 2003), whereas lack of migration to wintering areas suggests that adequate winter habitat was available in reaches where trout also spend the summer (Young 1998). Some radio-tagged fish in our study over-wintered in areas containing minimal small woody debris or cobble-boulder habitat (Last Chance through Harriman East), even though adult rainbow trout have been observed to utilize these structures for concealment during winter days in nearby rivers (Meyer and Gregory 2000). However, other winter habitat features were available in these reaches including submerged aquatic macrophytes and deep pools. These habitat types have also been observed to provide winter cover for adult trout (Heggenes et al. 1993, Cunjak 1996).

Few rainbow trout from downstream reaches are represented in the population estimate that takes place in the monitoring area each spring. Assuming that the movements of our radio-tagged fish are representative of similarly sized untagged trout, between 6 and 12 percent of the ~ 1700 fish > 300 mm present in 2008 from Last Chance through Lower Harriman (IDFG unpublished data) could be expected to be present in the monitoring area when the population estimate is typically completed. This would mean that 102-204 fish from downstream would be represented in the population estimate. The estimated number of fish in the Box Canyon monitoring area fluctuates between 3,700 and 12,900 fish > 150 mm (Garren et al. 2008). Therefore, immigrating trout from down-river could represent 0.7 to 5.4 percent of the estimated number of trout in Box Canyon.

Because migrant fish from downstream are a small portion of the Box Canyon population estimate, downstream fish numbers could fluctuate widely (maybe even by a factor of 10) and independently of Box Canyon fish numbers and not be noticed. For example, if the total Box Canyon population estimate were low, e.g., 4,000 fish, and the fish numbers from downstream increased by a factor of ten, then instead of 200 fish from downstream reaches moving into the monitoring area, 2000 fish could have moved to that area. This would result in an increase in the population estimate from 4000 fish to 6000 fish, a 50-percent increase, but it is unlikely to suggest to managers that fish numbers downstream have increased 10-fold. When fish numbers in Box Canyon are high, fluctuations in fish numbers downstream would be even more obscured. Fish numbers in Box Canyon and areas downstream likely fluctuate together based on some factors such as drought (Erman 1986, Binns 1994), but also may fluctuate independently based on changes in macrophyte abundance, which are an important component of trout habitat downstream from Box Canyon but not in Box Canyon (Van Kirk and Martin 2000). Given the dynamic changes recently observed in macrophyte density and species composition (Van Kirk and Martin 2000, Henry 2010) in the Last Chance and Harriman reaches, regular trout population estimates within that area are needed to reflect fish population trends in those reaches.

Between 8 and 23 percent of our radio-tagged rainbow trout moved upstream out of the monitoring area during any given 8-day period in May 2005, however, it does not necessarily follow that the same proportion of all sizes of untagged fish moved out of the monitoring area. The movement we observed likely reflects spawning movements, which would be expected to involve only the mature adult portion (> 400 mm) of the population. The lack of movement out of the monitoring area by radio-tagged fish < 400 mm supports this hypothesis. In 2005, fish > 400 mm made up 41 percent of rainbow trout captured in the monitoring area (IDFG unpublished data). Therefore, maximum upstream spawning emigration may involve 9 percent of the total population, which is the 23 percent maximum observed emigration rate of radio tagged fish x 41 percent of fish in the population that are > 400 mm and therefore likely to move upstream.

An accurate population estimate for the marking period is based on two assumptions 1) no births or immigration between the mark and recapture periods, and 2) deaths and emigration between those periods affects marked and unmarked fish equally (Gatz and Loar 1988). Therefore, if these assumptions were met, the actual population estimate of 4430 (95% confidence interval 3922-4937) rainbow trout > 150 mm in the monitoring site during 2005 (Garren et al. 2008) should accurately portray the fish present during the marking period. To assess if emigration may have affected the estimate, and therefore what the estimated population would be during the recapture period (after the emigration had occurred), we removed 19 marked fish (23% of the marked fish > 400 mm) from the analysis and calculated a new hypothetical population estimate using the same log-likelihood estimator used by Garren et al. (2008). These calculations yielded a hypothetical population estimate of 4369 (95% confidence interval 3863-4874) rainbow trout > 150 mm. These two estimates are not significantly different as evidenced by their overlapping confidence intervals.

Sources of potential error, besides emigration, exist in the population estimate conducted in the monitoring area each spring. While this study showed that immigration from downriver into the monitoring area is relatively small, we do not know the extent of immigration into the monitoring area from the area between Island Park Dam and the mouth of the Buffalo River, upstream from the monitoring area. Additionally, even though no radio-tagged trout died in Box Canyon during May, a few untagged fish may experience spawning related mortality within the monitoring area during this time period.

The primary use of the population estimate for management purposes is not to identify the absolute number of individuals per se, but rather to compare the population estimate obtained with previous and subsequent population estimates to determine whether the population is increasing or decreasing. These comparisons will be biased if detection probabilities are differentially affected by such things as emigration; subsequently, statistical tests should be run to determine if detection probabilities are equal among comparison years (MacKenzie and Kendall 2002).

Based on our study, there may be a relatively easy way to eliminate some of the potential effects of detection probabilities from emigration. During May, migration from the monitoring area by radio-tagged rainbow trout only included movements upstream, into the area between Island Park Dam and the mouth of the Buffalo River. Therefore, this emigration from the monitoring area could be eliminated by extending the monitoring area upstream to Island Park Dam. However, this may cause additional problems such as estimates from the extended monitoring area may not be comparable to estimates from the current monitoring area because fish density may be higher in the added area. Also, the additional time necessary to sample fish in the extended area may result in fewer marking runs being completed, ultimately expanding confidence intervals and making changes in the population more difficult to detect. Another way to eliminate some effects of fish movement or mortality is to conduct the population estimate during the fall when emigration and mortality rates are lower than during the spawning period. However, this is a popular fishery and conducting estimates during the fishing season could be socially unacceptable. After 30 November, when the fishing season has ended, discharge from Island Park Dam is reduced to facilitate storage of irrigation water and is typically too low to conduct an estimate.

Conclusions

- Survival of radio tagged trout in Box Canyon during early winter was 100 percent at low and extremely low flows.
- Consideration of juvenile trout needs may be more important in formulating winter flow regimes below hypolimnetic release dams than are the needs of adult trout.
- Trout movement among radio-tagged rainbow trout in Box Canyon was similar during the extremely low flow period and during a corresponding time period the following year.
- Trout from downstream reaches are present in Box Canyon during May, when population estimates are conducted, but these fish are a small proportion of the overall estimated population. Therefore, fish density fluctuations in downstream reaches could be extensive and yet not be apparent within the population monitoring area in Box Canyon.
- Given the dynamic habitat conditions in the Last Chance and Harriman reaches, regular trout population estimates within that area are needed to reflect fish density trends in those reaches.
- Emigration between the mark and recapture periods of the population estimate causes the estimate to calculate the number of trout present in the monitoring area during the mark period. However, a hypothetical population estimate, which accounted for emigration of marked fish, was not significantly different from the actual population estimate.
- Deciphering trends in population abundance in the monitoring area should include analyses to determine whether detection probabilities are the same.

- Differences in detection probabilities among years may be lessened by extending the monitoring area upstream to Island Park Dam. However, additional monitored length could introduce other problems.

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Bat Species Presence in Southwestern Montana

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Abstract
Published information on bat species presence in many parts of Montana is limited. Our study was initiated to gather data on the distribution of bat species found in the southwestern part of the state. We captured 106 individuals of eight bat species in mist-nets at 15 water sources in southwestern Montana during July through August 2003-2006. The western long-eared myotis (*Myotis evotis*) was the most frequently captured species and detected at over half the sites surveyed. Other common species captured across numerous sites included little brown myotis (*M. lucifugus*), hoary bats (*Lasiurus cinereus*), and big brown bats (*Eptesicus fuscus*). These species are apparently broadly distributed throughout southwestern Montana, occurring in a variety of habitat types. Our study provides some much needed baseline data on bat distribution in southwestern Montana.

Key words: bats, Chiroptera, distribution, Montana

Introduction
Bats are important components of terrestrial ecosystems (Fenton 1997). They have low reproductive rates for mammals their size (Hill and Smith 1984), which makes their populations slow to recover from high levels of mortality. Thus, potential for factors such as habitat alteration, environmental change, and more recently white nose syndrome (Blehert et al. 2009) to cause declines in bat abundance has led to a focus on bats by many natural resource agencies. However, data necessary to develop effective conservation plans for bat species are often lacking. Even such basic information as species distribution is not available for many locations (Saugey 1991, Pierson 1998).

In Montana, published records on bat species distribution and abundance are limited and cover only parts of the state. Nicholson (1950) provided the first record of a spotted bat (*Euderma maculatum*) found in a home in Billings. Swenson (1970) published data on distribution of the western small-footed myotis (*Myotis ciliolabrum*) in eastern Montana. Hoffman et al. (1969) made the first attempt to summarize distribution of numerous bat species in the state based on specimens collected by the Public Health Service for rabies work in the late 1950s through the 1960s. The majority of these collected bats came from Missoula and Ravalli counties in western Montana. The work of Jones et al. (1973), Lampe et al. (1974), and Shryer and Flath (1980) added information on bats present in Carbon County in southeastern Montana. Swenson and Bent (1977) provided a list of species present in Yellowstone County in south-central Montana while Swenson and Shanks (1979) documented bats at three sites in northeastern Montana. Most recently Hendricks et al. (2000) documented species present in the Little Rocky Mountains of the north-central part of the state. Published data on presence of bat species in other parts of Montana is still limited. Our study was initiated to gather preliminary data on the distribution of bat species found in the southwestern part of the state.

Study Area
This study was conducted in southwestern Montana on USDI Bureau of Land Management (BLM) holdings of the Butte Field Office. These holdings are located in Jefferson, Broadwater, Lewis and Clark, and Silver Bow Counties. Bats were surveyed at 15 different sites located

across these holdings. Sites were selected based on their accessibility and the presence of permanent water sources. Elevations at these sites ranged from ~ 1300 m to 2100 m.

To examine patterns of distribution by different bat species, we classified each survey site into 4 habitat types: S = water sources surrounded by sagebrush (*Artemisia* spp.), D = water sources surrounded by Douglas- fir (*Pseudotsuga menziesii*), C= streams lined with large deciduous trees such as cottonwood (*Populus* spp.), or quaking aspen (*Populus tremuloides*), W = streams lined with riparian shrubs (predominately *Salix* spp.).

Methods

This study was conducted during mid July-early August, 2003-2006. At each site, we captured bats using 36-mm mesh, 50 denier, 2.1-m x 5.4-m mist-nets placed in locations considered to be suitable flyways for bats, such as open pools of water or clearings in stands of trees. The number of nets used per site varied but ranged from two to four. Nets were opened ~ 1 hr before sunset and kept open for 3-5 hrs depending on activity. Captured bats were identified to species and data on body measurements, sex, reproductive condition of females, and age (juvenile vs. adult) were recorded. We assessed reproductive condition by examination of the lower abdomen and mammary glands (Racey 1988). We aged bats based upon the degree of epiphyseal-diaphyseal fusion of wing bones (Anthony 1988). We identified species based on published keys and species accounts (van Zyll de Jong 1985, Adams 2003, Nagorsen and Brigham 1993). Western long-eared myotis (*M. evotis*) and fringed myotis (*M. thysanodes*) were distinguished from one another by ear length (van Zyll de Jong 1985). Specifically, the western long-eared myotis has an overall ear length that exceeds 50 percent of the forearm length and when the ear on the western long-eared myotis is pressed forward it extends ≥10 mm beyond the tip of the nose (van Zyll de Jong 1985). All captured bats were released after handling. Handling procedures were approved by Montana Fish,Wildlife, and Parks.

Results

We identified a total of 106 individuals of eight species from 15 water sources in 22 trap nights from southwestern Montana (Table 1). Survey effort varied by site. The majority of sites were only surveyed once but several sites were surveyed twice and one site was surveyed five times (Appendix A).

Western long-eared myotis and fringed myotis were the most abundant species captured, each made up over 20 percent of total captures. The western long-eared myotis was the most broadly distributed species within the study region (Tables 1 and 2). This

Table 1. Number of bats captured by species from Southwestern Montana, July-August, 2003-2006.

Bat Species	Number Captured (No.males, No. females)	Percentage of total captures	Percentage of Sites where captured
Western Small-footed Myotis (*Myotis ciliolabrum*)	6 (5, 1)	5.7	26.7
Western Long-eared Myotis (*M. evotis*)	23 (17, 6)	21.7	53.3
Little Brown Myotis (*M. lucifugus*)	13 (10,3)	12.3	26.7
Fringed Myotis (*M. thysanodes*)	22 (22,0)	20.7	20.0
Long-legged Myotis (*M. volans*)	12 (4, 8)	11.3	20.0
Hoary Bat (*Lasiurus cinereus*)	13 (10, 3)	12.3	40.0
Silver-haired Bat (*Lasionycteris noctivagans*)	7 (6, 1)	6.6	26.7
Big Brown Bat (*Eptesicus fuscus*)	10 (8, 2)	9.4	40.0
Total	**106 (82, 24)**	**100.0**	

Table 2. Occurrence of bat species by locality (see Appendix 1) and habitat type (S = water sources surrounded by sagebrush (*Artemisia* spp.), D = water sources surrounded by Douglas-fir (*Pseudotsuga menziesii*), C= streams lined with large deciduous trees such as cottonwood (*Populus* spp.), or quaking aspen (*Populus tremuloides*), W = streams lined with riparian shrubs (predominately *Salix* spp.) for each species in southwestern Montana , July-August 2003 - 2006.

Bat Species	Localities (Appendix 1)	Habitat Type
Western Small-footed Myotis (*Myotis ciliolabrum*)	1,6,7,8	S, D, C
Western Long-eared Myotis (*M. evotis*)	1,2,4,5,6,8,9,11	W, S, D, C
Little Brown Myotis (*M. lucifugus*)	1,2,5,14	W, S, D
Fringed Myotis (*M. thysanodes*)	1,2,3	W, S, D
Long-legged Myotis (*M. volans*)	2,13,14	W, S, D
Hoary Bat (*Lasiurus cinereus*)	1,2,5,12,14,15	W, S, D, C
Silver-haired Bat (*Lasionycteris noctivagans*)	5,7,11,14	W, D
Big Brown Bat (*Eptesicus fuscus*)	1,2,5,8,10,14	W, S, D

species was captured at over 50 percent of the sites surveyed and occurred in all habitat types at elevations ranging from 1470 m to 1770 m (Appendix A). Other broadly distributed species included hoary bats (*Lasiurus cinereus*) and big brown bats (*Eptesicus fuscus*), both of which were captured at 40 percent of sites. Hoary bats were captured in all habitat types while big brown bats were captured in three of the four. While relatively high numbers of fringed myotis were captured, the majority of these individuals (73%) were all captured at one site (Appendix A). Western small-footed myotis (*M. ciliolabrum*) and silver-haired bats (*Lasionycteris noctivagans*) were the least abundant species captured, but even though few individuals of these species were captured they were captured across multiple sites, habitats, and elevations.

Almost 80 percent of individual bats captured were males (Table 1). For all species, with the exception of long-legged myotis (*M. volans*) close to twice as many males compared to females were captured. No female fringed myotis were captured at any of the survey sites. Of the small number of female bats that were captured (*N* = 24), the majority (67%) were reproductive (lactating) at the time of capture. The percentage of lactating females ranged from 0% for hoary bats (*N* = 3) and western small-footed myotis (*N* = 1) to 100 percent for silver-haired bats (*N* = 1) and big brown bats (*N* = 2). Percentage of captured females that were lactating was 83, 83, and 33 percent for long-legged myotis, western long-eared myotis, and little brown mytois, respectively. Females were captured at elevations ranging from 1340 m to 1780 m (Appendix A).

Discussion

We recorded the presence of 8 bat species at 15 sites in southwestern Montana. Fifteen bat species occur in Montana with 12 of these species believed to be distributed in the western part of the state (Foresman 2001). The four species believed to be present in this part of the state that we did not capture were townsend's big-eared bat (*Corynorhinus townsendii*), spotted bat, California myotis (*M. californicus*), and Yuma myotis (*M. yumanensis*). Echolocation calls of spotted bats are audible to the human ear, allowing species recognition without direct capture (Leonard and Fenton 1983). However, we did not audibly detect this species during any of our surveys. Montana is the north-eastern-most extension of the range of both California myotis and Yuma myotis (Foresman 2001) and it may be that both species are uncommon in the western part of the state. However, others (Hoffmann et al. 1969) have found California myotis to be relatively common in the Bitterroot Valley in far western Montana. Townsend's big-eared bats have been documented in the counties that we surveyed (Foresman 2001). This species is found in a variety of habitats but it exists in low densities throughout its range (Humphrey and Kunz 1976, Kunz and Martin 1982). Townsend's big-eared bats are also known to be highly maneuverable and agile fliers (Fellers and Pierson 2002) which make them difficult to capture in mist-nets. It is likely that they may have been present at some of the sites we surveyed but a greater survey effort would be needed to detect them (Weller and Lee 2007).

Fringed myotis were captured at three sites. This species is one of the six bat species designated as Sensitive by the Montana State Office of the BLM and one of six species listed by the state as a Species of Concern. It has previously been collected in lower elevation forest regions in the state (Foresman 2001). We captured only males of this species and only at the high end of the range of elevations we surveyed. Many studies have reported elevational differences in distribution among sexes of insectivorous bats (Fenton et al. 1980, Grindal et al. 1999, Cryan et al. 2000) with females occurring at lower elevations.

Thorough knowledge of the current distribution of any species is necessary to maintain existing populations. This study contributes some important preliminary information on bat distribution in southwestern Montana and identifies sites that may be useful for future studies. However, much work remains to be done. Activity patterns of bats have been found to vary both spatially and temporally (Hayes 1997, 2000) and it is likely that our surveys did not detect all bat species present at individual sites. More surveys and multiple surveys at individual sites are recommended as well as studies that focus on roost and foraging site selection.

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Appendix A.

Locations of survey sites and species examined from southwestern Montana 2003-2006.

1. **Soap Gulch, Silver Bow Co., Montana.** G[1], E0373125 N50621362, 1830 m. 29 July 2003 (9 net hrs). Western Long-eared Myotis (1 male). 31 July 2003 (16 net hrs). Western Small-footed Myotis (2 males), Western Long-eared Myotis (1 male), Little Brown Myotis (1 male), Fringed Myotis (5 males), Hoary Bat (1 male), Big Brown Bat (1 male).
2. **Moose Creek, Silver Bow Co., Montana.** W, E0370035 N5066854, 1780 m. 1 August 2003 (16 net hrs). Little Brown Myotis (1 male), Fringed Myotis (16 males), Long-legged Myotis (2 females), Hoary Bat (2 males, 1 female), Big Brown Bat (1 male). 19 July 2004 (6 net hrs). Western Long-eared Myotis (5 males), Little Brown Myotis (5 males), Long-legged Myotis (3 males, 2 female). 23 July 2004 (9 net hrs). Little Brown Myotis (1 male). 19 July 2005 (8 net hrs). Long-legged Myotis (1 male). 26 July 2006 (6 net hrs). Long-legged Myotis (1 female), Hoary Bat (1 male).
3. **West Fork, Silver Bow Co., Montana.** D, E0348436 N5078288, 2100 m. 8 August 2003 (8 net hrs). Fringed Myotis (1 male).
4. **Cottonwood Canyon, Jefferson Co., Montana.** G, E0430659 N5080910, 1470 m. 20 July 2004 (8 net hrs). Western Long-eared Myotis (3 males).
5. **Upper Whitetail, Jefferson Co., Montana.** W, E0406504 N5097199, 1725 m. 17 July 2004 (7 net hrs). Little Brown Myotis (2 females, 1 male), Hoary Bat (4 males), Silver-haired Bat (1 male), Big Brown Bat (2 males). 24 July 2004 (6 net hrs). Western Long-eared Myotis (2 females), Little Brown Myotis (1 female), Big Brown Bat (2 males).
6. **Lower Whitetail, Jefferson Co., Montana.** C, E048619 N5093058, 1550 m. 16 July 2004 (6 net hrs). Western Small-footed Myotis (1 female), Western Long-eared Myotis (1 male, 2 females). 21 July 2005 (6 net hrs). Western Long-eared Myotis (2 males, 1 female).
7. **Big Pipestone, Jefferson Co., Montana.** D, E0399363 N5087441, 1560 m. 13 July 2004 (6 net hrs). Western Small-footed Myotis (1 male), Silver-haired Bat (1 male).
8. **Upper Halfway, Jefferson Co., Montana.** D, E0399358 N5089984, 1660 m. 14 July 2004 (8 net hrs). Western Small-footed Myotis (2 males), Western Long-eared Myotis (3 males), Big Brown Bat (1 male).
9. **Lower Halfway, Jefferson Co., Montana.** W, E0399572 N5088456, 1615 m. 15 July 2004 (7 net hrs). Western Long-eared Myotis (1 male).
10. **Lower Camp Creek, Silver Bow Co., Montana.** G, E0372520 N5056169, 1670 m. 21 July 2004 (8 net hrs). Big Brown Bat (1 male).
11. **Fish Creek, Silver Bow Co., Montana.** D, E0393478 N5073503, 1775 m. 20 July 2005 (6 net hrs). Western Long-eared Myotis (1 female), Silver-haired Bat (4 males).
12. **Crow Creek, Broadwater Co., Montana.** C, E0448048 N5122216, 1415 m. 4 August 2006 (6 net hrs). Hoary Bat (1 female).
13. **Lower Bigfoot Creek, Jefferson Co., Montana.** G, E0412510 N5106591, 1600 m. 28 July 2006 (6 net hrs). Long-legged Myotis (2 females).
14. **Lump Gulch, Jefferson Co., Montana.** D, E0419972 N5148619, 1340 m. 29 July 2006 (8 net hrs). Little Brown Myotis (1 male), Long-legged Myotis (1 female), Hoary Bat (2 males), Silver-haired Bat (1 female), Big Brown Bat (2 females).
15. **Virginia Creek, Lewis and Clark Co., Montana.** C, E0394331 N5193915, 1500 m. 1 August 2006 (7 net hrs). Hoary Bat (1 female).

[1]Habitat Type (see Table 2).
[2]Universal Transverse Mercator (UTM) Coordinates recorded in NAD 83.
[3]Net effort = number of nets X hrs open.

Effect of Rock Cover on Small Mammal Abundance in a Montana Grassland

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Abstract

We examined the influence of rock cover, as an indicator of presumable retreat site availability on the abundance of deer mice (*Peromyscus maniculatus*) and prevalence of Sin Nombre virus (SNV) using long-term live trapping and habitat data from three live trapping grids and a short-term (three month), spatially replicated study across three slopes in Cascade County, Montana. In our long-term study, we found that deer mice were more abundant at a live-trapping grid with greater rock cover, than two grids with less rock cover. There was a non-significant trend (P = 0.053) for deer mice to be more abundant in rocky sites in the short term study. In the long-term study, average SNV antibody prevalence among deer mice was slightly greater (5.0 vs. 3.5 % on average) at the live trapping grid with more rock cover, than the grid with less rock cover. We were unable to demonstrate differences in SNV antibody prevalence among treatments in the short-term study. Further studies are needed to elucidate the multiple determinants of deer mouse abundance and SNV prevalence in grassland ecosystem and other habitat types.

Key words: deer mouse, *Peromyscus maniculatus*, Sin Nombre virus, retreat sites

Introduction

The abundance of small mammals varies temporally and spatially among and within habitat types (e.g., Krebs, 1996). In many cases, however, the underlying determinants of variability in small mammal abundance are unknown. Variation in abundance can have consequences for pathogen transmission because host abundance may influence contact and transmission rates among individuals in a population (Keeling and Rohani 2008). For example, human incidence of nephropathia epidemica (caused by *Puumala hantavirus*) was related to abundance of the host *Clethrionomys glareolus* in Sweden (Niklasson et al., 1995). Studies that examine determinants of host abundance in nature, and the effects these factors may have on pathogen prevalence, are needed to help reduce human exposure.

Deer mice (*Peromyscus maniculatus*) are widespread omnivorous rodents, which occur in a variety of habitat types across North America (Kirkland and Layne 1989, Douglass et al. 2001). These rodents have been ideal organisms for studies of habitat relationships for many decades (e.g., Smith 1940, Douglass 1989, Matlack et al. 2001, Johnston and Anthony 2008) and in Montana their abundance varies among and within many habitat types (e.g., Douglass et al. 2001). Deer mouse abundance has been found to be positively related to shrub cover in a short grass prairie environment (Stapp and Van Horne 1997) throughout central and western Montana (Douglass 1989a, Douglass et al. 2001) and Western Colorado (Douglass 1989b). Furthermore, deer mice are reservoirs for Sin Nombre

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virus (SNV, *Bunyaviridae:Hantavirus*) (Nichol et al., 1993), a directly transmitted zoonotic pathogen that is transmissible to humans causing Hantavirus Pulmonary Syndrome (HPS), which has a high mortality rate (CDC, 2009). The abundance of deer mice is an important component of SNV transmission (e.g., Madhav et al. 2007) and human exposure risk (Childs et al. 1995). Both abundance of deer mice and SNV prevalence among mice can vary significantly over small spatial scales (Glass et al. 2000, Douglass et al. 2001). Therefore, studies that investigate variability in deer mouse abundance and how this is affected by habitat characteristics within an expansive habitat type are of value to understanding SNV transmission and human exposure risk.

In Montana deer mouse abundance and prevalence of antibodies to SNV are on average highest in sagebrush (*Artemesia tridentata*) dominated environments (Douglass et al. 2001), where sagebrush itself may provide retreat sites. However, deer mice can also be abundant, with high SNV antibody prevalence in other habitat types, such as grassland and forest environments (Kuenzi et al. 2001, Douglass et al., 2001). Here, we investigated how abundance of deer mice and prevalence of SNV antibodies varied within a grassland ecosystem located in Cascade County, Montana. We focused on rock cover, which may be an indicator of potential retreat site availability, as a determinant of variation in deer mouse abundance in this habitat type. Within this grassland several habitat characteristics were different among sampling locations and some, e.g., such as shrubs or patches of tall grass, may provide retreat sites for deer mice. However, we chose to focus on rock cover in this study because the abundance of deer mice at three long-term grassland live trapping grids differed (Douglass et al. 2001) as did rock cover. In addition, we frequently observed deer mice using rocks as retreat sites upon release from live traps. Although rock cover is clearly not critical to deer mouse survival in all habitats especially in open environments with high shrub cover (Douglass et al. 2001, Douglass 1989a, Douglass 1989b, Douglass and Frisina 1993), in this environment rock cover may be important for avoiding large predators, caching resources, or nesting. Other habitat characteristics differed among our long-term live trapping grids (see results) and likely also contributed to variation in deer mouse abundance within this grassland habitat type (Wecker 1963, Douglass 1989a, Douglass 1989b, Morris, 1997). The multivariate effect of habitat characteristics on deer mouse abundance will be the subject of further investigations.

We hypothesized that in a specific type of Northern Great Plain grassland, deer mice are more abundant, with a greater number of individuals and prevalence of SNV antibodies in the population, in sites with similar vegetative characteristics but greater rock cover (potential retreat site availability) than sites with less rock cover. We investigated the relationship between population abundance and prevalence of SNV in relation to rock cover in two ways. We used a long-term (1994-2010) study on population dynamics of deer mice on three live trapping grids and prevalence of SNV on two live trapping grids (Douglass et al. 1996, Douglass et al. 2001) from which our observations led to the hypothesis above. Because the long-term study lacked spatial replication in rock cover, we also undertook a short-term (three month) spatially-replicated study to evaluate the effect of rock cover on small mammal abundance.

Materials and Methods

Long-term data collection

Data on deer mice and habitat characteristics were collected on three one hectare grids (grid numbers 10, 11 and 12) located near Cascade (46° 59.3 N, 111° 35.3 W, 1408 m AMS), Montana. Grids were situated in grassland habitat supporting an active cattle ranch (Douglass et al., 1996). We live-trapped deer mice for three consecutive nights/month on all three 1-ha grids for 174 consecutive months between

June 1994 and November 2008. Trapping grids consisted of 100 equally-spaced Sherman live traps (H. B. Sherman Traps. Tallahassee, Florida), baited with rolled oats and peanut butter and provisioned with polyester Fiberfil bedding. Upon capture, each rodent was given a uniquely numbered ear-tag (model #1005-1, National Band and Tag Co., Newport, KY) and species, gender, body mass, reproductive condition, and presence of scars or wounds were recorded. We routinely collected blood samples, which were later tested for antibodies to SNV, from grids 11 and 12 only. We followed animal handling, blood collection and safety precautions described by Mills et al. (1995) and approved by the University of Montana IACUC. Serological testing was performed at the Montana State Public Health Laboratory and at Special Pathogens Branch, U.S. Centers for Disease Control and Prevention, using methods described by Feldmann et al. (1993).

We used the enumeration technique of Chitty and Phipps (1966) to provide a minimum number of individuals known to be alive (MNA) during a 3-day trapping session as an index of population abundance for each month. The minimum number of deer mice antibody-positive to SNV (MNI) during each trap session was calculated in the same way for grids 11 and 12. Estimated antibody prevalence (EAP) of deer mice for a given month was calculated by dividing MNI by MNA (Mills et al. 1999a).

Data on habitat characteristics of the three long-term grids were collected twice annually (Jun and Sep) at 25 randomly-assigned locations/grid using a 10-pin point frame. Percent cover of lichens mosses, grass, forbs, shrubs, rock, leaf litter and bare ground was determined at each location. A contact with rock and a point frame rod was counted as rock cover. Although, direct use of rocks as retreat sites by deer mice was not quantified in this study, our assumption of rocks offering retreat sites seemed reasonable. Although our analysis did not directly account for use of rocks as retreat sites we found (1) large rocks that mice were able to move beneath were present at all sites, (2) small burrows were common around rocks at our sites, (3) mice were frequently observed retreating to rocks for cover when released from traps, and (4) mouse tracks and burrows in snow commonly originated from rocks.

Short-term Data Collection

To determine if abundance of deer mice differed among sites with more or less rock cover (retreat sites), we established six 0.25-ha grids on three slopes (named Hill One, Hill Two and Hill Three for this study) of approximately the same elevation and aspect. Within each slope, one grid was located in a rocky area and one in a non-rocky area. Grids were live-trapped for small mammals monthly from August-October 2008 in the same manner as the long-term live trapping grids, but with 25 equally spaced rather than 100 Sherman live-capture traps. Small mammal handling, testing for SNV antibodies, calculation of MNA, MNI rock cover, and SNV prevalence among deer mice was carried out in the same manner as the long-term trapping grids. In September, we also measured habitat characteristics at each of the six grids in the same way as the long-term grids, but with habitat characteristics determined from six randomly-assigned locations at each grid (a similar proportion/unit area as the long-term grids).

Analyses

We employed a Friedman analysis (Zar, 1996) to determine if abundance of deer mice, number of deer mice antibody positive for SNV, and antibody prevalence among deer mice differed among long-term trapping grids. A Friedman analysis was also used to determine if habitat characteristics differed among the long-term grids over time. Friedman analysis enabled examination of direction of differences among variables for individual sampling occasions collectively and, accordingly, was independent of the effects of seasonal and climatic forcing on dynamics, which are certainly important but beyond the scope of this investigation. For the short-term study, habitat characteristics among grids were compared using a Generalized Linear Model (GZLM), with hillside as a random effect. Optimal distribution and transformation of data (Poisson or negative binomial probability distribution and identity or log-link function respectively) for the GZLM were specified using an Omnibus test. A linear mixed model (LMM) was used to determine if deer mouse abundance and antibodies to SNV among deer mice (number antibody positive and antibody prevalence) differed between rocky and non-rocky sites, with month as a repeated measure and hillside as a random effect. All analyses were performed using SPSS 15.0 (SPSS Inc. Chicago, U.S.).

Results

Over the 15-yr long-term study, we captured 4458 individual deer mice 12,265 times in 155,700 trap-nights of effort. Abundance of deer mice fluctuated among months and years. Average monthly abundance of deer mice was greatest at grid 11 (MNA = 25.8), least at grid 12 (MNA = 15.3), and intermediate at grid 10 (MNA = 22.9) (Table 1). The average monthly number of antibody positive deer mice (MNI) and estimated antibody prevalence (EAP) was greater at grid 11 (MNI = 1.3, EAP = 0.05) than grid 12 (MNI = 0.3, EAP 0.035) (Table 1). However, on several occasions during 15 yrs of sampling, both grids 11 and 12 experienced many months with no presence of antibody-positive deer mice (Luis et al. 2010). Among the three long-term live trapping grids we detected significant differences in each of the habitat variables except bare ground (Table 2). Of particular focus in this study, rock cover was greatest at grid 11 (0.556 %) and least at grid 12 (0.147 %; Table 2).

We initially confirmed that the proportion of cover that consisted of rock was greater among sites we had selected as rocky sites, than non-rocky sites, in the short-term study (Table 3). Cover of most other habitat variables did not differ, except cover of lichens, which were found exclusively on rocks (Table 3). Over the 3-mo short-term study, 172 individual deer mice were captured 381 times in 1350 trap-nights. Deer mouse abundance was greatest at Hills One and Two and least abundant at Hill Three (Table 4). Average deer mouse abundance was higher at rocky sites than non-rocky sites but this difference was not statistically significant (Tables 4 and 5). The number of deer mice antibody positive for SNV and deer mouse antibody prevalence was unrelated to rocky or non-rocky habitat (Tables 4 and 5).

Discussion

Determining factors that influence zoonotic host abundance is important to understanding pathogen transmission, and subsequently human exposure risk. Here, we investigated if abundance of deer mice (a host reservoir for SNV) in a grassland

Table 1. Mean (± SE) abundance of deer mice, , number of antibody positive deer mice to SNV (MNI) and antibody prevalence of deer mice (EAP) for the three long-term (Jun 1994-Nov 2008) live trapping grids. SNV data was collected for grids 11 and 12 only. Friedman analysis comparing rodent abundance and SNV infection data among grids. Significant results in bold.

		Live trapping grid			Friedman analysis		
		10	11	12	X^2	df	*P*
Deer mice	mean	22.9	25.8	15.3	155.780	2	**< 0.001**
	SE	1.651	1.388	1.211			
MNI	mean		1.3	0.3	40.238	1	**< 0.001**
	SE		0.157	0.044			
EAP	mean		0.05	0.035	21.248	1	**< 0.001**
	SE		0.005	0.007			

Table 2. Mean (± SE) percent cover of habitat types for the three long-term (Jun 1994-Nov 2008) live trapping grids and Friedman analysis of how vegetation cover differed among grids. Significant results in bold.

		Bareground	Rock	Moss	Lichens	Leaf Litter	Grass	Grass Height	Forbs	Shrubs
10	Mean	0.2	0.4	0.1	0.1	8.6	7.7	18.4	2.1	0.5
	SE	0.057	0.106	0.071	0.018	0.455	0.415	7.0	0.372	0.100
11	Mean	0.2	0.6	0.9	0.2	7.4	6.6	14.3	1.5	0.2
	SE	0.059	0.090	0.2	0.068	0.523	0.458	5.868	0.243	0.091
12	Mean	0.2	0.1	0.000	0.02	8.9	8.5	22.7	1.1	1.3
	SE	0.07	0.042	0.000	0.017	0.427	0.350	8.213	0.238	0.163
	X^2	0.03	17.643	32.411	17.930	22.769	35.766	10.308	13.470	31.735
	df	2	2	2	2	2	2	2	2	2
	P	0.983	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**	**0.006**	**0.001**	**< 0.001**

ecosystem was related to availability of rock cover, i.e., as an indicator of potential refuge site availability, and if prevalence of SNV antibodies was positively related to deer mouse abundance between rocky and less rocky areas. Using long-term data from three live trapping grids, we found deer mice more abundant at a site with more rock cover, than sites with less rock cover over many years. Deer mice were on average more abundant at rocky sites in the short-term study, but this was a non-significant trend ($P = 0.053$). Based on the long-term study, we also found the number and prevalence of SNV antibody positive deer mice was greater at sites with more rock cover, than sites with less rock cover, which supported our hypothesis. Our short-term study did not detect a significant difference in SNV between sites with more or less rock cover, which could have been due to the short duration and relatively low number of deer mice trapped.

Habitat characteristics varied among the three long-term grids in this study. This variation in habitat composition, in addition to rock cover, included moss, lichens, grasses, forbs, shrubs, and leaf litter. Among the three long-term grids, more deer mice were captured where cover of rocks, moss and lichens were high, and fewer were captured where cover of leaf litter, grasses and shrubs were high, suggesting these variables could all be determinants of deer mouse abundance in this grassland ecosystem. In previous work (Douglass 1989b) found a negative correlation between deer mouse abundance and grass cover. Douglass et al. (2001) also reported deer mice to be more abundant in sagebrush habitats in Montana. Shrubs in the current study area were mostly snowberry (*Symphoricarpus* spp.) with a growth form quite different from (particularly density of stems over the ground) sage. Collectively, our study, Douglass (1989b), and Douglass et al. (2001) indicated that deer mice are captured in less complex habitat matrices. We focused on rock cover as a source of variation in deer mouse abundance because of rock cover's potential use as retreat sites by deer mice. While releasing deer mice after capture we often observed them seeking refuge under rocks. In this grassland environment other types of retreat sites (such as logs and thick shrub cover) are absent or rare.

The habitat composition in our short-term study only differed by rock cover and lichens (which were observed on rocks only) among rocky and non-rocky grids. However, deer mice were generally but not statistically significantly so, more abundant at rocky grids. Our long-term study demonstrated that the number of deer mice with SNV antibodies and SNV antibody prevalence was higher on the grid with greater deer mouse abundance. This lends support to our hypothesis linking rock cover, host

Table 3. Mean (± SE) percent cover of vegetation types among hillsides and sites within hillsides for the short-term (Aug-Oct 2009) study. Generalized Linear Model of how vegetation types differ between rocky and non-rocky areas, with variables nested within hillside. Significant results in bold.

	Hill One		Hill Two		Hill Three		GZLM	
	Non-rock	Rock	Non-rock	Rock	Non-rock	Rock	$X^2_{1,5}$	P
Bare ground	2.2(1.014)	1.2(0.792)	0.8(0.543)	0.7(0.333)	0.2(0.167)	1.2(0.792)	8.293	0.141
Rock	0.82(.307)	1.3(0.667)	0.8(0.833)	2.8(1.641)	0.5(0.5)	1.3(0.667)	11.456	**0.043**
Lichens	0.82(.307)	1.0(0.516)	0.2(0.167)	2.5(1.455)	0.3(0.333)	1.0(0.516)	17.857	**0.003**
Grass	5.2(0.91)	8.0(0.775)	9.0(0.516)	6.3(0.989)	8.0(0.856)	8.0(0.775)	1.203	0.945
Grass height	35.7(9.017)	31.5(5.005)	30.3(3.201)	34.0(3.812)	31.2(5.134)	31.5(5.005)	3.671	0.598
Leaf litter	7.0(0.816)	7.5(1.057)	8.3(0.843)	6.5(1.522)	9.0(0.516)	7.5(1.057)	3.124	0.681
Forbs	2.7(0.333)	1.5(0.619)	1.5(0.563)	0.8(0.543)	1.2(0.401)	1.5(0.619)	6.265	0.281
Biomass	7.8(1.350)	8.4(1.488)	15.0(5.046)	9.4(1.658)	13.0(2.674)	11.4(1.927)	4.675	0.322

Table 4. Abundance of deer mice, number of deer mice antibody positive to SNV (MNI) and antibody prevalence of deer mice (EAP) between rocky and non-rocky sites among hillsides for each trapping occasion, for the short-term (Aug-Oct 2009) study.

	Hill	Grid	Mice	MNI	EAP
Aug	One	Non-rock	6	0	0
		Rock	10	0	0
	Two	Non-rock	1	0	0
		Rock	22	3	13.6
	Three	Non-rock	0	0	0
		Rock	1	0	0
Sept	One	Non-rock	17	0	0
		Rock	17	0	0
	Two	Non-rock	7	2	28.6
		Rock	23	1	4.3
	Three	Non-rock	8	2	25.0
		Rock	15	0	0
Oct	One	Non-rock	30	0	0
		Rock	26	0	0
	Two	Non-rock	14	2	14.3
		Rock	27	4	14.8
	Three	Non-rock	10	0	0
		Rock	19	0	0

Table 5. LMM, with sampling occasion as a repeated measure and site as a random effect, of how abundance of deer mice (Mice), number of deer mice antibody positive for SNV(MNI), and antibody prevalence (EAP) differed between non-rocky and rocky sites, for the short-term (August – October 2009) study.

	$F_{1,4}$	P
Mice	7.403	0.053
MNI	0.300	0.613
EAP	1.128	0.432

abundance and pathogen abundance in this grassland ecosystem. This relationship suggests that SNV prevalence is positively related to deer mouse abundance, which is consistent with some studies (e.g., Calisher et al. 1999, Yates et al. 2002, Carver et al. 2011a, and Madhav et al. 2007 and Carver et al. 2011b in a delayed density fashion).

Transmission of SNV is horizontal due to intraspecific interactions among deer mice, such as aggressive encounters (Mills et al. 1997, Root et al. 1999, Botten et al. 2002). Intraspecific interactions among deer mice may increase with increasing abundance, resulting in increased transmission events.

Our short-term study did not detect a relationship of deer mouse abundance with the number of SNV antibody positive individuals. Our short-term grids were only 0.25-ha in size (consisting of 25 Sherman live traps each), which limited the number of deer mice that could be trapped compared to the numbers captured on the larger long-term grids. Given the size of trapping grids, the lack of detectable differences in SNV at rocky and non-rocky grids may be due to study design. Conducting this short-term, spatially replicated study for a longer period of time and with one hectare trapping grids may enable better detection of relationships between 1-ha rock cover, deer mouse abundance and SNV among deer mice across this grassland landscape.

Other habitat characteristics can also function as sources of retreat sites to deer mice, particularly in other habitat types, leading to variation in abundance and infection. Douglass et al. (2001) found deer mouse abundance and SNV prevalence was greater in sagebrush habitat (where deer mice may use sagebrush as retreat sites) than grassland and forest habitats in western Montana. Root et al. (1999) found abundance of deer mice and the number of SNV positive individuals to be greater at a site dominated with sagebrush/juniper/pine than a site with oak/mixed grass /forbs in western Colorado. Lehmer et al. (2008), in a brief study, found deer mice were on average more abundant and with higher SNV prevalence at sites with less mechanical (off road vehicle) anthropogenic disturbance in the Great Basin Desert, Utah. However, in general, deer mice have been found to increase in numbers when habitats were opened by grazing (Smith 1940, Douglass and Frisina 1993, Matlack et al. 2001, Johnson and Anthony 2008) and forest treatments (Sullivan 1979, Douglass et al. 1999).

Our informal observations indicate that deer mice use rocks as retreat sites throughout the year. However, variation in deer mouse abundance across this landscape is likely related to a complex combination of habitat, climatic, and density dependant variables (i.e., Luis et al. 2010). It is also possible that at certain times of the year predators, such as weasels and snakes during summer months, may influence use of rocks by deer mice. Future spatially replicated analyses of other significant relationships among habitat characteristics and deer mouse abundance, particularly using multiple long-term studies, would be valuable to delineate all the underlying habitat determinants in this grassland ecosystem landscape. Studies evaluating interactions among retreat site use, other fauna and climatic factors would also be valuable. Telemetry studies (Douglass 1989a) and food habit studies (Van Horne 1982) would be valuable approaches to accurately determine how deer mice use this grassland habitat.

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presented here are those of the authors and do not necessarily represent the views of the funding agencies.

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Grazing Effects on Deer Mice with Implications to Human Exposure to Sin Nombre Virus

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Abstract

We examined the effects of grazing on deer mouse (*Peromyscus maniculatus*) movements into buildings using passive integrated transponder (PIT) technology and small simulated buildings located on 0.6-ha treatment (grazing) and control (no grazing) plots. Twelve experimental 9-day trials were conducted over the course of the study. During these trials, mouse movements into buildings were monitored during three time periods (each 3 days in length). In the treatment plots these time periods corresponded to pre-grazing, grazing, and post grazing by horses. The number of individual deer mice entering buildings over time decreased in both the grazed and control plots during the 9 days of each experiment. The number of entrances per/individual among the pre-grazing, grazing and post grazing periods was different between control and treated plots for both males and females. The distribution of entrances/individual among the three periods differed between males and females in both grazed and control plots. The habitat modification caused by grazing appeared to reduce deer mouse activity (entrances/individual) in buildings but does not affect the number of mice entering buildings. Reducing vegetative cover by grazing or mowing may not affect the number of mice investigating small structures but grazing creates different activity patterns in the structures for neighboring deer mice.

Key words: hantavirus, deer mouse, Sin Nombre Virus (SNV), *Peromyscus maniculatus*

Introduction

Ecological and environmental changes due to changing land use practices may provide opportunities for increased transmission of infectious diseases (Woolhouse and Gowtage-Sequeria 2005) by increasing human contact with zoonotic hosts, their ectoparasites, and the diseases they carry. Rodents, such as deer mice (*Peromyscus maniculatus*), are reservoir hosts for many infectious diseases, including hantaviruses (Morse 1995). Hantaviruses are rodent-borne pathogens that can cause serious human illnesses. In the United States, the deer mouse is the principal reservoir for Sin Nombre virus (SNV) (family Bunyaviridae, genus *Hantavirus*) (Childs et al 1994, Nichol et al. 1993). SNV causes Hantavirus pulmonary syndrome (HPS) a serious human illness with a fatality rate of 35 percent (CDC). In many HPS cases, human exposure to SNV has been linked to contact with infected rodents and/or their excreta in and around buildings (peridomestic settings) (Armstrong et al. 1995). However, the ecology of deer mice in peridomestic settings is not well understood (Kuenzi and Douglass 2009, Kuenzi et al. 2001), and little data exist on what causes deer mice to move from surrounding natural areas into peridomestic settings.

Modification of surrounding habitat is one factor that may cause mice to enter buildings. Livestock grazing is probably the most common habitat modification in Montana. Small mammal populations and communities can be directly and indirectly affected by grazing (Hayward et al. 1997). Trampling of burrows, compacting soil, and competition for food resources are direct effects of grazing, while altering vegetation structure that then influences habitat selection by small mammals is an indirect effect. Significant changes in the nutritional dynamics and physical structure of vegetation have been caused by grazing by both bison and cattle (Damhoureyeh and Hartnett 1997) and presumably horses. Such alterations could potentially cause deer mice to leave their normal habitat and enter peridomestic settings.

In an effort to improve our understanding of the relationship between anthropogenic environmental changes and human exposure to SNV, we examined the movement of deer mice into peridomestic settings in response to habitat modification (grazing). We hypothesized that grazing in areas around buildings would increase deer mice movement into those buildings. To test this hypothesis we monitored deer mouse movements into simulated buildings before, during, and after grazing by horses in the surrounding habitat. We used horses to graze the surrounding habitat because they were easier to control and move than cattle. The results from this study are necessary for the development of recommendations to help reduce the risk of human exposure to rodent borne diseases.

Methods

Study Site

This study was conducted near Gregson, Silver Bow County, Montana. The dominant vegetation at the study site consisted of antelope bitterbrush (*Purshia tridentata*), spotted knapweed (*Centaurea maculosa*), cheatgrass (*Bromus tectorum*), and big sagebrush (*Artemisia tridentata*).

Rodent Trapping and Processing

We conducted 12 experimental trials (9 days each) from April through June 2005; October through November 2005; February 2006; June through August 2007; and May through July 2008. Deer mice were trapped and marked 3 days prior to each trial. In each plot we attempted to saturate the plot with traps set in grids containing (see experimental design below), five rows of 25 traps (Sherman non-folding, aluminum life traps (8 x 9 x 23 cm, H.B. Sherman Trap Co., Tallahassee, Florida, USA), with 10-m spacing between traps, were set with the experimental buildings in the center of the grid, and checked each day for 3 consecutive days. Traps were baited with peanut butter and oatmeal and contained polyester bedding. All captured animals were transported to a central location for processing. Species, body mass, sex, age, and reproductive condition of captured animals were recorded. Deer mice were ear-tagged with monel #1005-1 tags (National Band and Tag Co., Newport, Kentucky). PIT tags (Passive integrated transponder tags, BioMark, Inc; Boise, Idaho) were adhered directly to the skin between the shoulders of each deer mouse. A small patch of fur was shaved away to secure the PIT tag closer to the animal. The adhesive was then used to coat over the PIT tag and glue the surrounding fur over the tag to help with tag retention. Based on modifications to methods used in previous work, (Kuenzi et al 2005) we assumed pit tag retention was nearly 100 percent for the duration of each trial. A hand held reader was used to verify that the PIT tags functioned after attachment. PIT tag numbers were then recorded and individuals were released at the point of capture.

Experimental Design

The effects of habitat modification (by grazing) on mouse entries into buildings and availability of food resources (rolled oats) within buildings were examined using a series of 12 experimental trials. For each trial, one treatment (grazing) plot and one control (no grazing) plot (0.6 ha) were used. Two small simulated buildings were placed in the center of each plot. Each simulated building was 2.44 m x 1.22 m x 1.22 m with a 5-cm diameter opening in one end. Our simulated buildings do not represent all features that actual outbuildings would present to mice; however, we feel the initial response by mice to simulated buildings would be similar to that of actual buildings. Further experimentation would be required to determine what would allow deer mice to establish residency in buildings. One building in each plot contained ~ 1 kg of rolled oats. An electrical fence was constructed around treatment pastures to control horses.

We equipped each building with a passive integrated transponder (PIT) tag transceiver (Model 2001F, Biomark Inc, Boise, Idaho) linked to an antenna located around the building opening. The antenna detected pit-tagged deer mice that entered/exited the building. The pit tag number, date and time of the entrance/exit were recorded in the transceiver. Transceivers in each building were activated in the evening and turned off every morning to conserve electricity. Each transceiver was powered by a 12-volt deep cycle battery charged by a solar panel. Transceivers were retrieved from the field in the morning and data from the previous night were downloaded onto a desktop computer. Movement into these buildings was monitored for 9 nights during each experimental trial.

Buildings in both the treatment and control plots were monitored 3 days prior to introducing the horses (pre-grazing). Both plots were monitored for 3 days with the horses in the treatment plot (grazing) and then monitored again for 3 days after the horses were moved out (post grazing). Six horses were used to graze each experimental plot. The horses basically removed all herbaceous vegetation (to within 2 cm of the soil) within the three days they were present in the treatment plots. All plots had an entire winter and growing season between trials.

Data Analysis

To determine if habitat modification by grazing would affect deer mouse entrances into our simulated buildings, we used Chi-square analyses (Zar 1984) to compare the numbers of individuals entering buildings (a numeric response) and the number of entrances/individual (a behavioral response) during the pre-grazing, grazing and post grazing periods between the control and grazed pastures summed across all trials. A *P*-value of 0.05 was used for all analyses.

It was logistically difficult to spatially replicate this experiment due to the large area necessary, a limited supply of horses, and the home range size of deer mice. Therefore, this experiment was replicated by performing multiple ($N = 12$) experimental trials. The location of treatment and control plots were randomized among a set of pastures within a single ranch. Accordingly, the 12 experimental trials were conducted over a relatively long period (Apr 2005 to Jul 2008) to enhance the independence of observations, i.e., reduce the probability that individual mice would become habituated to the experiment.

Results

Of the 174 deer mice fitted with PIT tags, 69 (39.7%) entered buildings at least once. Out of these 69 individuals, only four individuals entered buildings on all 9 days of a given trial. Across all trials and plots, 63 of the 69 individual mice entered buildings during the pre-grazing period, 42 during grazing period and 32 during the post grazing period. Some individual mice were recorded during multiple periods and were included in the number of individuals/period.

Across all trials in the treatment plots, we recorded a total of 26 individual mice entering buildings with 24 individuals entering during the pre-grazing period, 18 during the grazing period, and 14 during the post grazing period (Fig. 1). In the control plots across all trials, 43 individuals entered buildings with 39 mice entering the buildings during the pre-grazing period, 24 during the grazing period, and 18 during the post grazing period. Regardless of treatment, the number of mice entering the buildings was greatest during the first 3 days of the trial (pre-grazing period) and smallest during the last 3 days of each trial (post grazing period; Fig. 1). The number of individuals entering buildings among periods was similar between control and treated pastures ($\chi^2 = 0.017$, $P > 0.05$) (Fig. 1) with the number of individuals entering buildings declining in both control and treatment plots over the 9 days of a trial. In control plots 18 individual deer mice accounted for 87 percent of movements into buildings whereas nine individuals accounted for 70

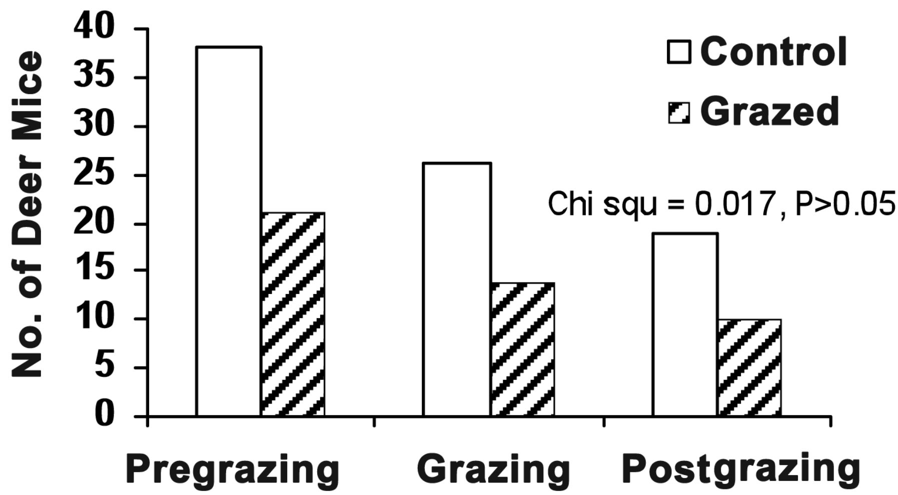

Figure 1. The number of deer mice entering simulated buildings in grazed versus control (non-grazed) plots in Southwestern Montana from 2005 through 2008.

percent of the movements into buildings.

The behavioral response (number of entrances/individual) was significantly different between control and grazed plots for both females ($\chi^2 = 7.68$, $P < 0.05$) and males ($\chi^2 = 95.68$, $P < 0.001$; Fig. 2). The number of female entrances into buildings in grazed plots decreased over 9 days but remained fairly constant in the control plots. Male entrances also decreased in the grazed plots but increased in the control plots from one period to the next.

Males and females responded differently in terms of numbers of entrances per individual through the duration of a trial in both the grazed plots ($\chi^2 = 12.38$, $P < 0.05$) and the control plots ($\chi^2 = 26.36$, $P < 0.001$; Fig. 3). However, overall responses differed in the grazed plots compared to the control plots. Both female and male entrances decreased over the nine days in the grazed plots with males decreasing more than females. In the control plots, male entrances/individual increased during the nine days while female entrances remained relatively constant. Most animals in the experiments were adults thus sample sizes were insufficient to test age related responses and sample sizes were insufficient for seasonal comparisons.

The presence of food had no effect on entrances/individual in the grazed plots (food vs. no food, $\chi^2 = 1.68$ $P > 0.05$). However in the control, entrances/individual increased continuously in the building with food and remained fairly constant in the building with no food over the nine days ($\chi^2 = 17.67$, $P < 0.001$; Fig. 4).

Discussion

Research on the effects of livestock grazing on deer mouse ecology has yielded various results for different vegetation types (Douglass and Frisina 1993, Clary and Medin 1992, Medin and Clary 1989, Oldemeyer and Allen-Johnson 1988). In this study we found no difference in the number of individuals entering buildings in grazed versus ungrazed plots. Our movement data are consistent with Oldemeyer and Allen-Johnson (1988), who found little or no difference in deer mice abundance between grazed and ungrazed sites with dominant vegetation types of spotted knapweed, antelope bitterbrush, and cheatgrass.

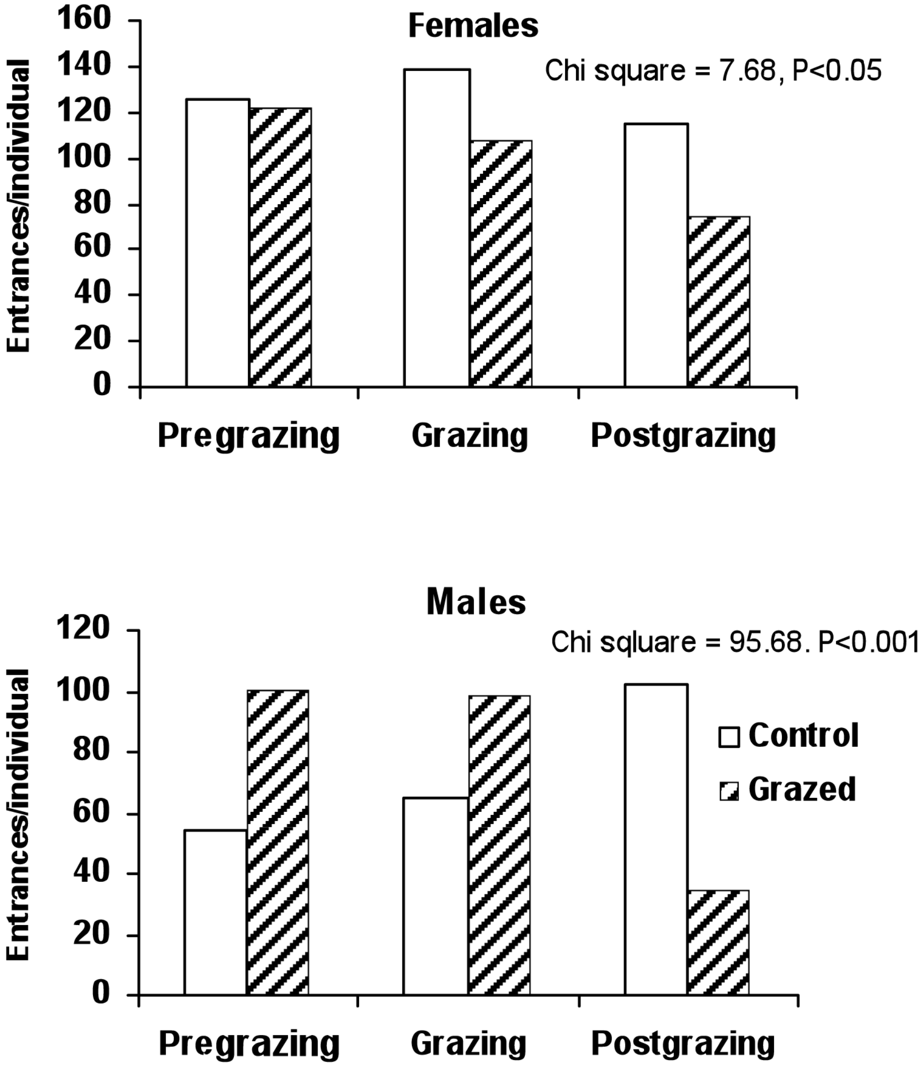

Figure 2. The number of entrances/individual mice into simulated buildings located in control (non-grazed) versus grazed plots in Southwest Montana from 2005 through 2008.

In our study, the number of mice entering simulated buildings declined over the 9-day period of each experimental trial. This reduction in numbers over time was most evident in the control plots of the study in the absence grazing, suggesting that the longer mice had access to buildings, the less the mice were "inclined" to enter them. Fewer mice may have entered over the duration of the study possibly because after initial investigations, they found the simulated buildings unsuitable or they may have left the area entirely.

However, we detected activity to differ between control and grazed plots for both males and female deer mice, as represented by number of entrances into buildings per individual. Activity decreased over the 9-day duration of experimental trials in the grazed plots but in the control plots it remained fairly constant for females and increased for males (Fig. 3). In grazed plots deer mice may possibly have been using a new resource, e.g., seed in horse manure, instead of entering buildings or the mice hesitated to move across open areas to access the

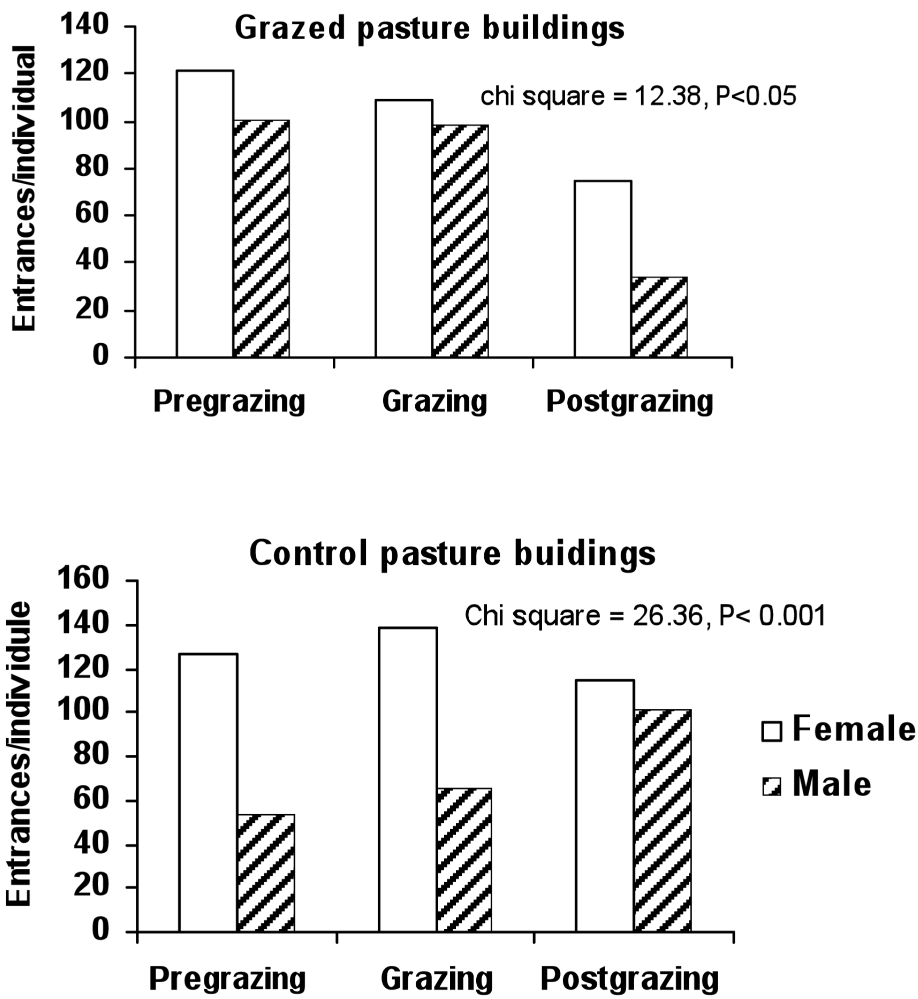

Figure 3. Response of female versus male deer mice to grazing expressed as the number of entrances/individual mice into simulated buildings located in control (non-grazed) versus grazed plots in Southwest Montana from 2005 through 2008

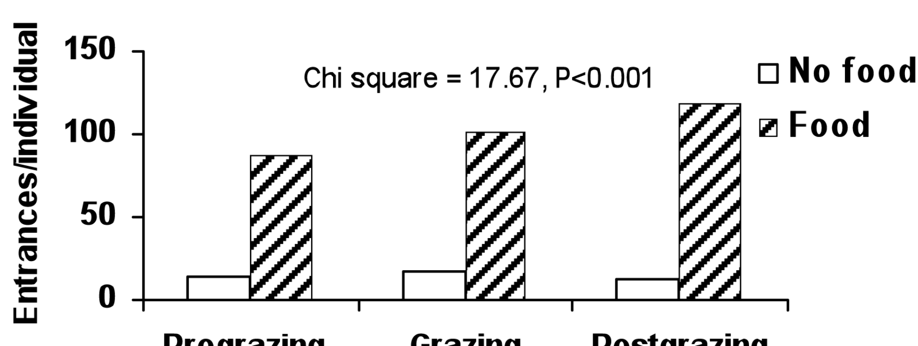

Figure 4. Effects of food in simulated buildings on the distribution of entrances/ individual deer mouse in non-grazed pastures in Southwest Montana from 2005 through 2008. Animals responded to food and non-food buildings equally in grazed pastures.

buildings. The increase in activity by males in the control plots may have been due to the presence of food in one of the buildings. In a previous study, presence of food significantly increased activity represented by entrances into buildings (Kuenzi and Douglass 2009). However, the effect of food only occurred in the control plots and not in grazed plots. Why male activity would increase and female activity did not is unclear. Perhaps males could shift activity to the new food resource more easily than females that may have had litters in nests some distance from the buildings.

Previous research has shown that adult males are the most likely to become infected with SNV (Douglass et al. 2007) as well as to disperse (Lonner et al. 2008). If males are more likely to enter or are more active in peridomestic systems upon sylvan disturbance (grazing in this instance) than females, grazing could increase chances for human exposure to SNV. However, grazing did not increase the number of either males or females entering buildings but did modify the behavioral response (number of entrances/individual). The males increased activity in buildings located in the control plots during the duration of the trials but decreased activity into buildings located in the grazed plots. This may indicate that grazing in small areas around buildings may reduce human exposure to SNV in buildings.

The simulated buildings do not replicate all resources presented to deer mice in normal houses, barns and sheds. Normal buildings are much more complex, larger and provide places for nesting, hiding and caching food. The resources provided by normal buildings would affect how deer mice used the buildings once the outside environment was modified differently than our simulated buildings did. However, the simulated buildings do provide insight into the initial response (entering) of deer mice to habitat modification surrounding buildings.

Information on factors that draw mice into buildings is necessary to better understand the relationship between peridomestic and sylvan settings. This understanding is necessary to design proper health measures to protect humans from SNV. More research, perhaps with more severe and expansive habitat modification than was created by a few days of grazing and more complex buildings is necessary to clarify the influences of habitat modification on deer mice entering buildings. However, our preliminary results suggested that grazing may reduce activity of male mice in buildings.

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General Abstracts

Alphabetical By First Author's Last Name

(* Denotes Presenter)

Evaluation of wildlife Guards at Access Roads

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The reconstruction of 90.6 km of U.S. Highway 93 from Evaro to Polson, MT on the Flathead Indian Reservation includes 41 fish and wildlife crossing structures and 13.4 km of road with wildlife fencing. These measures are aimed at reducing wildlife–vehicle collisions, while allowing wildlife to cross the road. In fenced road sections, gaps for side roads are mitigated by wildlife guards (similar to cattle guards). We focused on a 1-km fenced section where animals can either cross the road using five crossing structures (4 culverts, 1 bridge), or they can access the road through two guards on the east side and cross using jump-outs, i.e., earthen ramps that allow animals in fenced areas to jump down to safety, on the west side. We monitored wildlife movements with cameras at the two guards and in one large crossing structure adjacent to a guard. We investigated how effective these guards are in keeping deer (*Odocoileus* spp.) from accessing the road. We also compared movements across a guard to those through a crossing structure. The guards were 85 percent or more effective in keeping deer from accessing the road, and 93.5 percent of deer used the crossing structure instead of an adjacent guard when crossing the road. Though the guards were not an absolute barrier to deer, the results indicated that deer were substantially discouraged from crossing the guards, and the vast majority crossed the road using the crossing structure rather than the guard, indicating that guards are an effective means of mitigation.

Using Cameras Effectively To Monitor Wildlife

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There are two important wildlife management issues that can be solved by using the appropriate wildlife camera. The first is human interference in wildlife behavior studies. As much as researchers try to do everything possible so animals won't notice their presence during a study, most wildlife have a keen senses that alert them to humans nearby and cause them to react differently to situations. Using motion-sensored cameras eliminates the human factor and allows wildlife to behave more naturally. Another important issue that wildlife conflict managers come across is not having enough time in the day. Our study used remote uploading, wireless wildlife cameras to help biologists involved in conflict management situations with grizzly bears (*Ursus arctos horribilis*). The biologists were able to easily set up the cameras near residents who had complained of grizzly bears damaging property. Having the cameras automatically upload pictures allowed the biologist to observe the wildlife conflicts and the status of the deterrent measures from a remote location. The biologists could view the pictures almost immediately through their email and know what was occurring at the site. If there was a trap or deterrent set up, the biologist could see whether an animal was caught and needed to be removed, or could similarly observe that the trap was empty and would save themselves a trip to the site. This saved innumerable man hours of physically checking the traps and conflict sites and even saved the life of an owner's dog that had unknowingly been trapped in a leg snare.

How To Trick A Wolf: Manipulating Pack Movements With Biofencing

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Wolves (*Canis lupus*) have a relatively wide distribution in the northern Rockies and can conflict with livestock production in certain areas. Tools currently available to mitigate wolf/livestock conflict can be short-lived in their effectiveness or altogether ineffective. Wolves use scent-marking to establish territories and avoid intraspecific conflict. We hypothesized that human-deployed scent-marks could be used to manipulate wolf pack movements in Idaho. We deployed 64.7 km of biofence within three wolf pack territories during summer 2010. Location data from collared wolves showed little to no trespass of the biofence. Sign surveys at predicted rendezvous sites yielded little to no recent wolf use of exclusion areas. Lastly, a habitually depredating wolf pack was not implicated in any depredations. Our pilot test provides preliminary evidence that wolf movements can be manipulated using human-distributed scent-marks.

Wolf Management In The Northwestern United States

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Gray wolves (*Canis lupus*) were deliberately eliminated from the northern Rocky Mountains (NRM) by 1930. Restoration began in 1986. There are currently nearly 120 breeding pair and 1800 wolves. Wolf restoration initially proceeded with more benefits and fewer problems than predicted. However, conflicts have steadily increased since 2002 when the population first met its minimum recovery goal. About $40 million has been spent since 1974 and the management program currently costs >$4 million/yr. Wolves were delisted in 2008 and 2009 but relisted by federal court order in 2009 and 2010. While the NRM wolf population is biologically recovered, public opinion remains divisive and the legal, political, and policy decisions will continue to be litigated by a diversity of interests. Science is a poor tool to resolve the differing human values that continue to be debated with great passion through wolf symbolism.

Current Status Of Trumpeter Swan Reintroduction At The Flathead Indian Reservation

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The Confederated Salish and Kootenai Tribes, in partnership with other agencies and non-governmental organizations, commenced a project to reintroduce trumpeter swans (*Cygnus buccinator*) at the Flathead Indian Reservation in 1996. Between 2002 and 2010 191 swans were released on the Reservation. Released swans generally wintered locally in the lower Flathead River drainage and its tributaries, likely due to mild winter weather conditions, abundant open water and ample food resources. Wintering swans from the project were also observed in southwestern Montana, northeastern Colorado and eastern Idaho, but few of these known migrants survived. Collisions with overhead power lines accounted for the majority of documented mortalities. Cooperative efforts with the local electrical utility are underway to mark lines and the marking seems to have reduced the incidence of collision mortalities. The first wild-nesting trumpeter swans from the reintroduction project were observed in 2004 with continued successful nesting each subsequent year and a total production of 89 fledged cygnets. Future plans for the reintroduction project include additional releases of captive-reared swans, continued monitoring of released and wild hatched swans, wetland habitat restoration projects, and marking of additional power lines.

Avian Scavengers And Lead Rifle Ammunition: Where We're At, Challenges, And Solutions

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Birds have long been recognized at risk of lead poisoning from ammunition sources, but only in recent years has rifle ammunition been identified as a source of lead toxicity in raptors and other scavenging birds. Several studies have indicated increased lead exposure in eagles but the implications to population dynamics remain unclear. We have monitored blood lead levels of Common Ravens (*Corvus corax*), Bald Eagles (*Haliaeetus luecocehpalus*), and Golden Eagles (*Aquila chrysaetos*) in Jackson Hole, Wyoming, since 2004 to investigate effects of spent rifle ammunition on avian scavengers. Data from ravens and Bald Eagles indicated a strong relationship between big-game hunting seasons and elevated blood lead levels. In 2009, we initiated a voluntary non-lead ammunition program in collaboration with Grand Teton National Park and the National Elk Refuge. Free, non-lead ammunition was distributed to hunters in the area. Hunter surveys indicated that 24 percent of successful hunters on the Park and Refuge used non-lead ammunition and we detected a 28-percent drop in the mean lead levels of ravens monitored from previous years after the harvest totals were controlled for. We continued the voluntary program in 2010 by selling reduced-priced non-lead ammunition, and there was greater participation in the voluntary non-lead program (33%). Further, we have outfitted 13 Bald Eagles with satellite transmitters to document the potential geographic impact our local hunting season has on the continental eagle population and found that 90 percent of eagles outfitted during the big-game hunting season breed/summer in central Canada.

Landscape-Scale Conservation And Management Of Montane Wildlife: Contemporary Climate May Be Changing The Rules

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Both paleontological and contemporary results have suggested that montane ecosystems to be systems of relatively rapid faunal change compared to many valley-bottom counterparts. In addition to experiencing greater magnitudes of contemporary change in climatic parameters than species in other ecosystems, mountain-dwelling wildlife must also accommodate often-

greater intra-annual swings in temperature and wind speeds, poorly developed soils, and generally harsher conditions. Research on a mountain-dwelling mammal species across 15 yrs of contemporary data and historical records from 1898-1956 suggest that pace of local extinctions and rate of upslope retraction have been markedly more rapid and governed by markedly different dynamics in the last decade than during the 20th century. This may mean that understanding past dynamics of species losses may not always help predict patterns of future loss. Given the importance of clinal variability and ecotypic variation, phenotypic plasticity, behavioral plasticity, and variation in climatic conditions, for widely-distributed species' geographic ranges to be determined by different factors in different portions of their range is not uncommon. Consequently, greatest progress in understanding distributional-change phenomena will occur with coordinated, landscape-scale research and monitoring. Landscape Conservation Cooperatives and Climate Science Centers are newly emerging efforts that may contribute greatly to such broad-scale investigations, e.g., climate-wildlife relationships. Based on our empirical findings and our review of related literature, we propose tenets that may serve as foundational starting points for mechanism-based research at broad scales to inform management and conservation of diverse montane wildlife and the ecosystem components with which they interact.

Evaluating The Genetic Distinctiveness Of The Salmon River Drainage Bighorn Sheep And Their Connectivity To Neighboring Populations

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Rocky mountain bighorn sheep (*Ovis canadensis canadensis*) were historically abundant in Idaho, but currently population levels remain low. Bighorn Sheep (BHS) in the Salmon River drainage are considered one of Idaho's only remaining native sheep populations because they were never completely extirpated from their historic range. In addition, there has been little or no genetic influence via translocation of sheep from outside the drainage potentially making this BHS population genetically unique to Idaho. Contrastingly, surrounding populations to the west and east were extirpated or severely reduced and have subsequently been reintroduced or heavily augmented through use of translocations from Canada and several western states. There is presumably some degree of population connectivity between the Salmon River sheep and surrounding areas but to date, this has not been investigated using genetic data. To assess the genetic distinctiveness of Salmon River bighorns and their connectivity to other populations, we have collected genetic data from 15 nuclear DNA microsatellite loci for 256 BHS using blood and horn shaving samples across a 33,786-km2 study area in central Idaho. The number of BHS genetic groups will be determined using Bayesian clustering algorithms, and the degree of connectivity between populations will be examined using Fst and assignment tests. Future directions include comparing radio-location data and genetic information to investigate structure/connectivity and potential for disease transmission of SRD bighorns as well as examining relationship between lamb productivity/survival and genetic diversity/gene flow.

A Regional Analysis Of Factors Affecting Adult Female Elk Survival

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The Western Elk Research Collaborative has pooled elk (*Cervus elaphus*) telemetry data from seven states, one Canadian province, and Yellowstone National Park. We have collected data from 3550 individual elk across 51 populations. The vast spatial scale of this analysis affords us an unprecedented opportunity to understand how natural ecological conditions and human changes to the environment influence survival of this critical segment of the population. We use proportional hazards models and information-theoretic approaches to assess how predator diversity, harvest by humans, habitat conditions, land use, climatic factors, and interactions between these factors affect adult female survival across the region. Most of our variables are uniform within a given population, but we also assess the effects of "age" at the individual level. Some variables such as land tenure, road density, and forest cover are considered temporally static for the purposes of this study, whereas others such as precipitation, climate, and density dependence could vary over time within each population. The survival estimates we generate will ultimately help inform decision-support tools that managers could use at statewide and regional scales to explore how harvestable numbers of elk are influenced by management of habitat and predation in the context of climatic and habitat changes.

Winter Ecology Of The Shiras Moose On The Mount Haggin Wildlife Management Area

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Moose (*Alces alces shirasi*) populations across Montana have expanded in the last century, both in geographic range and in population size. This expansion has had a negative impact on moose winter range in some locations where moose have overutilized key browse species. Excessive and unsustainable browsing has the potential to reduce local biodiversity and carrying capacity of moose and other ungulates. The browse species of interest in this study were willow (*Salix* spp), a highly palatable and abundant browse source for moose on many winter ranges, including our study area in southwestern Montana. The objectives of this study were to determine patterns of willow community use by selected female moose during winter and to quantify willow utilization across the study area to examine population scale habitat use through browse patterns. To accomplish these objectives we deployed GPS collars on 18 cow moose, 6 each in the winters of 2007, 2008, and 2009-2010. We also completed large scale, systematic browse surveys in the springs of 2008, 2009 and 2010. Results indicated cow moose spent the plurality of the winter within willow communities (48.4%, 48.2%, 51.8%, and 49.8% of locations in the winters of 2007, 2008, 2009, and 2010, respectively), but the estimated percentage of browsed willow twigs across the study area was low (11.5%, 8.0%, and 8.3% in 2008, 2009, and 2010, respectively). Our data suggest that while moose have the potential to significantly impact willow communities, this did not appear to be the case on the Mount Haggin WMA at current moose densities.

What Can We Learn From Calf/Cow Ratios?

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Trends in population growth can be monitored with data for key vital rates without requiring knowledge of abundance. Adult female survival has the highest elasticity for ungulate population dynamics, but the more variable recruitment rates can be better predictors of local variation in growth rates. Recruitment is often monitored using young adult age ratios, which are difficult to reliably interpret given the contribution of multiple vital rates to annual ratios. We show how concurrent monitoring of adult female survival and age ratios allows both retrospective estimation of empirical population growth rates and the decomposition of recruitment-specific vital rates. We demonstrate the estimation of recruitment and population growth rates for one woodland caribou population using these methods, including elasticity and life-stage simulation analysis of the relative contribution of adult female survival and recruitment rates to variation in population growth. We show, for this woodland caribou population, that adult survival and recruitment rates are nearly equivalent drivers of population growth rates. We recommend the concurrent monitoring of adult female survival to reliably interpret age ratios when managing caribou and other ungulates.

Stable Isotope Analysis Of Summer Wolf Diet In Northwestern Montana

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When distinct δ13C and δ15N values of potential prey are known, stable isotope analysis (SIA) of wolf (*Canis lupus*) hair can be used to estimate diet variability at the individual, pack, and regional levels. Our objectives were to estimate intra-population diet variability, and determine proportions of prey consumed by wolves. We collected guard hairs of 45 wolves from 12 packs in northwestern Montana and temporally matched scats from 4 of the same packs, summer 2008 and 2009. We used hierarchical Bayesian stable isotope mixing models to determine diet and scales of diet variation from δ13C and δ15N values of wolves, deer (*Odocoileus* spp.), elk (*Cervus canadensis*), moose (*Alces alces*), and other prey. We calculated percent biomass of prey consumed from scats, and used bootstrapped scat data,

and Markov Chain Monte Carlo simulation data from stable isotopes to estimate confidence intervals of difference between results from each technique for the 4 packs with matched samples. Differences among packs explained most variability in diet based on stable isotopes, and moose was the most common prey item for 11 of 12 packs. From scat data, deer was the most common prey item for 3 of 4 packs, and estimates of moose consumed were significantly different from SIA estimates for the same 3 packs. The proportion of moose in wolf diet may have been overestimated by SIA because wolf-specific fractionation values were not available. Stable isotope analysis has the potential to efficiently provide useful management information, but experimentally derived fractionation values for wolves would likely improve the accuracy of estimates in future studies.

The Status Of Golden Eagles In The West: Migration, Breeding, And Energy Infrastructure

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Golden Eagles (*Aquila chrysaetos*), are widespread raptors, breeding predominately in western North America, from northern Alaska to central Mexico, occupying a wide range of habitats from arctic tundra to deserts. Several studies have recently indicated decreasing population estimates for migrant and wintering Golden Eagles in the western US. Long-term point count surveys of migrating raptors along the Rocky Mountain Front flyway have indicated approximately a 50-percent decline in total autumnal and vernal Golden Eagle migrants observed over the past 15 yrs and suggest the rate of decline has been increasing. Regionally, specific populations in the Lower 48 and parts of Alaska have been well studied on their breeding grounds. Some of these populations appear to be stable, while others show declines. Observed declines, appear to be associated with habitat alterations. Oil and gas resource extraction has increased noticeably across many areas of the West. The demand for resource extraction is growing and now includes renewable energy facilities such as wind farms. Due to the greater than ever human presence on the landscape and projected increases in development, it is critical to assess eagle response to these changes within their current and historic breeding, migration and winter ranges. Mapping current Golden Eagle habitat use, locally and at the landscape level to better understanding the relationships between human activities and eagle ecology, are the vital first steps to creating a balance between maintaining viable Golden Eagle populations and sustainable development.

Blood-Lead Levels Of Fall Migrant Golden Eagles In West-Central Montana

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Lead has long been documented as a serious environmental hazard to eagles and other predatory, opportunistic and scavenging avian species. The use of lead shotgun pellets for waterfowl hunting on federal and state lands was banned in 1991 due to lead poisoning in

Bald Eagles (*Haliaeetus leucocephalus*), Golden Eagles (*Aquila chrysaetos*) and numerous waterfowl species. At that time, this was thought to be the only major source of the lead exposure. More recently, lead poisoning from ingested lead-bullet fragments and shotgun pellets has been identified as the leading cause of death in California Condors (*Gymnogyps californianus*), leading to the recent ban of lead ammunition within the "California Condor Recovery Zone." Another on-going study on Common Ravens (*Corvus corax*) and Bald Eagles in Wyoming has shown a direct correlation between very high blood-lead levels and the on-set of rifle hunting season. Indeed, there is overwhelming evidence showing that lead toxicity is still prevalent in the environment and mounting data points to fragmented rifle bullets as the source. We sampled blood from 131 Golden Eagles captured on migration during the fall from 2006 and 2010 to quantify a suite of possible heavy metal contaminants, with an emphasis on lead.

The Dichotomy Of Conservation – Managing Elk In The Wildland/Urban Interface Of Missoula , Montana

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The Missoula Valley in western Montana is home to nearly 800 wintering elk (*Cervus elaphus*), including the North Hills, Evaro, Jumbo, O'Brien Creek and Miller Creek herds. With the City of Missoula as the hub, the Valley has experienced substantial human population growth over the last 30 yrs. This increased growth and subsequent development has consumed and fragmented wildlife habitat and placed additional recreational demands on adjacent public lands. Wildlife biologists with Montana Fish, Wildlife and Parks have worked cooperatively with local governments, federal agencies, land trusts, other non-governmental organizations, and the general public to conserve and protect important elk winter range and habitat connectivity within the wildland/urban interface of the Missoula Valley. From a biological perspective, we have been extremely successful in managing for the persistence of elk populations. However, protecting winter range adjacent to and fragmented by human development has additional management challenges and costs. Since 1980, the North Hills elk herd has grown an average of 11 percent per year, with a 48-percent growth rate occurring between 2000 and 2007. Without an effective harvest, this population is expected to double in less than seven years. To protect elk winter range and to continue to keep elk wild, wildlife biologists have needed to become more creative with their management and conservation strategies. This presentation discusses those strategies, as well as the dichotomy of conserving elk winter range and managing elk on human developed landscapes.

Montana Electronic Precipitation Map

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A new average annual precipitation map (AAP) has been developed for Montana using GIS techniques including universal Kriging and elevation dependent linear regression. The map can be updated with new base periods or used for different parameters. The current map

uses the 1981-2010 AAP base period and universal Kriging. Results were compared to hand-drawn maps to assure appropriate location of isohyets. Stations adjacent to Montana in Idaho, Wyoming, North Dakota, South Dakota, Alberta, and British Columbia were used to assure compatibility along the border and provide the capability to develop a comparable map for drainages flowing into Montana. Isohyetal lines were set at 2-in increments < 20 in AAP and 10-in increments > 20 in. Approximately 1400 stations were used for analysis of which ~ 1100 were in Montana and 300 in areas adjacent to Montana. AAP was estimated at snow courses using correlation between April 1 snow water equivalent and AAP from SNOTEL stations in their area. NWS Climatological stations and NRCS SNOTEL stations provided majority of locations having current AAP. Data from an old NWS storage precipitation gage network, NRCS storage gages, and RAWS stations were also incorporated as well as a few stations from individuals, USGS, USDA Forest Service, and others. To assure that precipitation at elevations above and below the data sites was applied correctly, synthetic points were developed using linear elevation-precipitation relationships from nearby measured sites. Maps will be available through Montana DEQ or Montana NRIS web sites electronically.

The Bird's-Eye View Education Program: Using Bird Research To Educate The Public On The Importance Of Healthy Riparian Systems

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The Upper Clark Fork River Basin (UCFRB) has been degraded by over 100 yrs of mining and smelting activities. The UCFRB is the largest contiguous complex of federal Superfund sites in the nation. Restoration and remediation efforts were initiated in the late 1980s and will continue, at a minimum, through 2030. Any restoration activity should include public education and outreach so that land-use decisions in the future do not compromise the integrity of the ecosystems that support the region. We have developed a program, the Bird's-eye View Education Program, which integrates public education and research on the ecological health of the UCFRB. Specifically we focus on birds, inviting the public to observe research at songbird banding stations and Osprey (*Pandion haliaetus*) nests. Riparian-associated birds are likely to respond positively to riparian restoration activities and can be used as bio-indicators to measure success. In 2010 we operated three bird banding stations and monitored 19 Osprey nests. We captured 595 songbirds, collected 43 blood and feather samples from Osprey chicks, and served nearly 1000 participants. The program was an outstanding success and results from an assessment show that participants leave with a positive attitude toward the outdoor science experience and a general knowledge of Upper Clark Fork restoration, history, and its riparian ecosystems.

The Mountain Ungulate Research Initiative: A Collaborative Effort To Advance Understanding Of Bighorn Sheep And Mountain Goat Ecology

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Bighorn sheep (*Ovis canadensis*) and mountain goats (*Oreamnos americanus*) are important components of the faunal assemblage of Montana's mountainous ecosystems representing high-profile large mammals that garner substantial public interest. While population restoration, augmentation, and introductions have traditionally been the predominant conservation activities associated with these species in Montana, basic ecological research has been limited. A new research initiative has been developed and funded to study bighorn sheep and mountain goat spatial and population ecology in a number of ecological settings within the Greater Yellowstone Ecosystem. The aspiration of the collaborators is to develop a long-term research program that could expand to other populations of these species in Montana if we are successful. Primary objectives of the studies include 1) understanding the ecological interactions between sympatric populations, 2) developing and refining habitat suitability models, 3) documenting spatial dynamics within and among populations and identifying important movement corridors, 4) collecting vital rate data to better understand population dynamics, and 5) investigating potential responses of bighorn sheep and mountain goats to gradual changes in the regional climate. The presentation will describe the collaboration and ongoing efforts to consolidate all available data on bighorn sheep and mountain goats in the GYE. These data are used to describe mountain goat range expansion within the GYE over the past half century and to conduct initial habitat modeling efforts. We will also describe our plans for initiating field studies in the near future.

Importance Of Recruitment To Accurately Predict The Impacts Of Human-Caused Mortality On Wolf Populations

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Reliable analyses can help wildlife managers make good decisions, which are particularly critical for controversial decisions such as wolf (*Canis lupus*) harvest. Creel and Rotella (2010) recently predicted substantial population declines in Montana wolf populations due to harvest, in contrast to predictions made by Montana Fish, Wildlife and Parks (MFWP). Here we replicate their analyses considering only those years in which field monitoring was consistent, and we consider the effect of annual variation in recruitment on wolf population growth. We also use model selection to evaluate models of recruitment and human-caused mortality rates in wolf populations in the Northern Rocky Mountains. Using data from 27 area-years of intensive wolf monitoring, we show that variation in both recruitment and human-caused mortality affect annual wolf population growth rates and that human-caused mortality rates have increased with the sizes of wolf populations. We also show that either recruitment rates have decreased with population sizes or that the ability of current field resources to document recruitment rates has recently become less successful as the number of wolves in the region has increased. Predictions of wolf population growth in Montana from our top models are consistent with field observations and estimates previously made by MFWP. Familiarity with limitations of raw data helps generate more reliable inferences and conclusions in analyses of publicly-available datasets. Additionally, development of efficient monitoring methods for wolves is a pressing need, so that analyses such as ours will be possible in future years when fewer resources will be available for monitoring.

Unicor: A Species Connectivity And Corridor Network Simulator

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Maintenance of species and landscape connectivity has emerged as an urgent need in the field of conservation biology. Current gaps include quantitative and spatially-explicit predictions of current and potential future patterns of fragmentation under a range of climate change scenarios. To address this need, we introduce UNIversal CORridor network simulator (UNICOR), a species connectivity and corridor identification tool. UNICOR applies Dijkstra's shortest path algorithm to individual-based simulations and outputs can be used to designate movement corridors, identify isolated populations, and characterize zones for species persistence. The program's key features include a driver-module framework, connectivity maps with thresholding and buffering, and graph theory metrics. Through parallel-processing computational efficiency is greatly improved, allowing for larger ranges (grid dimensions of thousands) and larger populations (individuals in the thousands), whereas previous approaches are limited by prolonged computational times and poor algorithmic efficiency; restricting problem-size (range and populations), and requiring artificially subsampling of target populations.

Functional Landscape Connectivity Of Greater Sage Grouse Habitat In A Multiple Use Landscape

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Maintaining connectivity of sage-grouse habitat is critical to managing sage-grouse populations in the presence of widespread human disturbance. We used an empirical approach to model connectivity of a landscape based on resource selection of free-ranging GPS-collared greater sage-grouse (*Centrocercus urophasianus*) in a natural gas field in central Wyoming. We analyzed resource selection during three movement states (encamped, traveling, and relocating) and incorporated turning angle to identify features that functioned as barriers or conduits to movement. To illustrate application of the results we used the resource selection model to create spatially-explicit predictive maps identifying areas that generally provided large amounts of high quality 'movement habitat.' We found that both males and females selected for vegetation variables at multiple spatial scales. When traveling or relocating, males and females tended to avoid natural gas and oil wells and associated infrastructure and avoided areas with high topographic roughness within 800m. High topographic roughness

was a barrier for traveling males. Relocating females were more likely to travel in a straight direction through areas of high road density and steep slopes. The predictive maps validated well using independent GPS location data. These results provide insight into habitat preferences of sage-grouse and can be used for both general and site-specific guidance on identifying habitats preferred or avoided during moderate and long distance movements of sage-grouse. When combined with critical seasonal use maps, e.g., nesting/brooding habitat and winter range, land managers could delineate areas of high value for connectivity of critical seasonal use areas.

Effects Of Recreational Disturbance On Mexican Spotted Owls On The Colorado Plateau In Southern Utah

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The Mexican spotted owl (*Strix occidentalis lucida*) was listed as a "threatened" subspecies in 1993 by the USDI Fish and Wildlife Service. In the Canyonlands of Southern Utah, the spotted owl is associated with fragmented habitats characterized by steep rocky canyons that attract high levels of human use for recreation, including climbing, hiking, hunting, and ORVs. Human-use levels have strongly increased in the canyonland region, e.g., permits for access to popular canyon hikes increased 1714 percent during 1998-2002 in Zion National Park. To assess owl population status and estimate effects of human-use on spotted owls, we conducted an occupancy-based research project during the 2008, 2009, and 2010 breeding seasons (defined as March-August). We designed our study to estimate occupancy rates and detection probability among owl territories in four areas: Zion and Capitol Reef National Parks, Grand Staircase-Escalante National Monument, and Cedar Mesa. A primary objective was to estimate the potential effects of human recreation on occupancy of the owl territories ("sites"). In addition to occupancy, we estimated reproductive status. Preliminary results from our data analysis showed varying occupancy rates, with 83 percent occupancy at mesic sites (Zion and Cedar Mesa), and 43 percent at xeric sites (Capitol Reef and GSENM). Detection probability was estimated to be 89 percent. Human use did not appear to reduce occupancy or detection. Reproduction varied by year, with 2009 showing the highest number of young, and several years with relatively low production of juveniles. Our results suggest that current management of human-use in our study areas is not adversely affecting occupancy and reproduction by Mexican spotted owls.

The Future Of Wildlife Education

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Students today need to be motivated to learn using methods that stimulate their creativity and excite them to look deeper into a subject on their own. As wildlife specialists we can contribute a unique expertise that teachers love to share with their students. With distance learning you can provide a virtual field trip for students in ≤ 30 min. Share your knowledge and love of animals and nature with students all over the world using videoconferencing technology. Be a part of raising the future generation of conservationists. During this presentation, we will show you how both Alter Enterprise and California State Parks use technology to engage students from afar and how any biologist can do the same from their own conservation area. Not only is this form of educational outreach exploding throughout schools, museums and libraries all over the world, but it is also creating a new love and understanding of wildlife that will hopefully show an increase of park and refuge visits by students who have had their interest sparked.

Unlocking Some Of The Untapped Value Associated With Our 20-Year Landbird Monitoring Database

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Twenty years ago, numerous partners initiated a region-wide landbird monitoring program. I will provide a brief history, will describe the data we now have in hand, and will present a few results that have important management implications. Finally, I will discuss the niche modeling potential buried in the data that we have amassed, and will propose that the strategic placement of additional monitoring points carries the greatest chance of yielding useful results for wildlife biologists who work for land management and conservation organizations. We hope to pilot the new approach within a 3-forest region associated with the Southern Crown's Collaborative Forest Landscape Restoration Partnership this year.

Multi-Scale Effects Of Forest Roads On Black Bears

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The black bear (*Ursus americanus*) population within the Coeur d'Alene River watershed of northern Idaho is exposed to high hunting and recreational pressure facilitated by a dense network of forest roads. Bears are hunted using bait and dogs in spring and fall, with an additional non-lethal summer pursuit season. To understand the effects of these roads on black bear behavior we used data collected from 28 adult bears fitted with Global Positioning Systems (GPS) collars from June 1 2007 through the fall of 2008. We used locations acquired at 20 minute intervals to assess habitat selection and activity patterns of males and females at home range (2nd order) and within home range (3rd order) scales, both annually and seasonally. We tested the hypotheses that black bears 1) will show no response to road density in 2nd order habitat selection in areas of relatively consistent road density, 2) will show a functional response to roads in 3rd order habitat selection, i.e., use of habitat near roads will be inversely proportional to traffic volume, 3) show seasonal shifts in activity patterns and movement rates in proximity to roads. Avoidance of areas containing primary food sources or increased activity and energy expenditure may have profound consequences for bears. Understanding how traffic volume and road density influences habitat selection and movement patterns can therefore play an important role in management of the species.

Grizzly Bear Population Augmentation In The Cabinet Mountains Of Northwest Montana

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The Cabinet Mountains grizzly bear (*Ursus arctos horribilis*) population was estimated at 15 or fewer individuals in 1988 and believed to be declining toward extinction. In response to this decline, a test of population augmentation techniques was conducted during 1990-1994 when four subadult female grizzly bears were transplanted to the area. Two criteria were identified as measures of success: bears must remain in the target area for one year, and bears should ultimately breed with native male grizzly bears and reproduce. Reproductive success of any of the remaining individuals could not be established until 2006 when genetic analysis of hair snag samples collected from 2002-2005 indicated that one of the transplanted bears remained in the Cabinet Mountains and had reproduced. The detected bear was transplanted in 1993 as a 2-year-old and was identified by a hair snag within 5 mi of the original release site. Genetic analysis indicated she had produced at least six offspring, and two of her female offspring had also reproduced. This reproduction indicates that the original test of augmentation was successful with at least one of the transplanted individuals. Success of the grizzly bear augmentation test prompted continuation of this effort. The Northern Continental Divide Ecosystem area of north central Montana has been the source of seven additional bears transplanted to the Cabinet Mountains during 2005-2010. All were female bears except one: a young male was moved in 2010. Two female bears were killed and two female bears left the area. Fates and movements of these bears are discussed.

History Of The Wall Creek Wildlife Management Area

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As the manager for the Wall Creek Wildlife Management Area for 34 years, I will provide an overview of the history of the FWP purchase of the Wall Creek WMA as well as an overview of the history of the grazing system and elk and livestock use of the game range.

Energetics And Space Use Of Female Moose During Winter In Alaska

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Space use and resource selection are a linked processes that are important determinants of individual and population fitness. Knowledge of those processes is important to understanding wildlife-habitat relationships. Knowledge of this information can improve the efficacy of wildlife management programs and provide baseline information in the face of changing environments. I present research findings investigating energetic and space use parameters of a population of female moose inhabiting two distinct, but adjacent, landscape types on the Kenai Peninsula, Alaska. I also examine how the inferences we derive from estimated space use patterns are influenced by the metrics we use to model space use by evaluating four contemporary home range models (Brownian bridges, fixed kernels, minimum convex polygons, and local convex hulls).

Quantifying The Predator-Prey Relationship: Lessons Learned From A Multiple-Prey, Wolf-Hybrid Zone In Algonquin Park, Ontario, Canada

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We studied winter kill rates and prey selection in an eastern wolf/moose/white-tailed deer system in Algonquin Park, Ontario Canada. Eastern wolves (*Canis lycaon*) are a distinct species, known to hybridize with both gray wolves and eastern coyotes, resulting in genetic variation within the study area. Deer in Algonquin are seasonally migratory, and accessibility of deer shifts significantly over winter. Some wolf packs migrate off territory to forage on deer, while others remain on territory, relying on moose. Our objectives were to 1) identify factors influencing variation in prey use, and 2) compare methodologies for quantifying prey use in a multiple prey system. We used fine scale GPS collar data to identify kill sites, and calculated relative use of moose and deer for each pack using several measures, including prey biomass/wolf/day, days/kill/pack and a newly developed method of time spent at kill sites from GPS data. We also conducted stable isotope analysis to compare with field collected prey-use data. Variation in prey use among wolf packs was most influenced by accessibility to deer, vulnerability of moose, and genetic admixture, and mediated by winter progression. Methodological comparisons showed that prey biomass/wolf/day tended to overestimate large prey items, while days/kill/pack overestimated the importance of small prey. Stable isotope results were inconsistent, revealing some possible weaknesses of this approach. We found wide variation in kill rates and relative prey use with winter progression, and spatial variation in age-specific predation associated with differences in hunter harvest pressure.

Twenty-One Years Of Harlequin Duck Surveys On The Rocky Mountain Front: Do We Know Anything Yet?

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Harlequin duck (*Histrionicus histrionicus*) surveys have been carried out continuously on the Rocky Mountain Ranger District (RMRD) for 22 years, beginning in 1990. Streams are surveyed on foot in spring to assess occupancy by breeding pairs, and in summer to count broods. Habitat and activity data have been collected for 247 separate observations (comprising > 600 individual ducks). We have summarized the habitats in which harlequins have been observed, including potential differences between pair and brood observations. Harlequins on the RMRD tend to be found in habitats similar to those described for other areas: in fast-moving segments of streams and in areas with shrub or tree overstory. Most observations are in areas accessible to, but not immediately adjacent to areas of human use. Most observations do not occur in proximity to within-stream woody debris, which may differ from findings elsewhere. We have not yet collected data with which to evaluate whether harlequin ducks actively select for any of these habitat characteristics. In 2007 three major fires burned on the RMRD, affecting several key harlequin breeding streams. We altered our survey areas to focus on the most historically productive stream system in the hopes of detecting any impacts of fire on harlequin occupancy or productivity. We have also begun to survey streams that have not been surveyed since the original 1990-1992 inventory. We provide possible explanations for the absence of harlequin ducks on several apparently suitable stream systems, and discuss the direction we hope to take with future surveys and analyses.

Climate Change Predicted To Shift Wolverine Distributions, Connectivity, And Dispersal Corridors

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Recent work has shown a link between wolverine habitat and persistent spring snow cover through 15 May, the approximate end of the wolverine's reproductive denning period. We modeled the distribution of snow cover within the Columbia, Upper Missouri and Upper Colorado River Basins using a downscaled ensemble climate model. We bracketed our ensemble model predictions by analyzing warm (miroc 3.2) and cool (pcm1) downscaled GCMs. Based on the downscaled ensemble model, 67 percent of predicted spring snow cover will persist within the study area through 2030-2059, and 37 percent through 2070-2099. Contiguous areas of spring snow cover become smaller and more isolated over time, but large (>1000 km2) contiguous areas of wolverine habitat are predicted to persist within the study area throughout the 21st century for all projections. By the late 21st century, dispersal modeling indicates that habitat isolation at or above levels associated with genetic isolation of wolverine populations becomes widespread.

The Effect Of Fix Rate And Fix Interval On First Passage Time Analysis

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First passage time analysis is a method of analyzing changes in animal movement along paths through habitats. First passage time is defined as the time required to traverse a circular region of a specified radius. Plots of variance in logged first passage times versus spatial scale have been used to help identify the scale at which search is concentrated. Two critical assumptions made when calculating first passage time are that movement is linear and speed is constant within a given circle. We investigate the robustness of first passage time results relative to these 2 assumptions using movement data collected on eight grizzly bears in the Greater Yellowstone Ecosystem. We found that the spatial scale identifying area restricted search was dependent on both fix interval and fix rate suggesting that how GPS collars are programmed influences first passage time results.

Avian Community Response To A Recent Mountain Pine Beetle Epidemic

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Recent epidemics of mountain pine beetles (*Dendroctonus ponderosae*) will fundamentally alter forests of the Intermountain West, impacting management decisions related to fire, logging, and wildlife habitat. We evaluated effects of a recent mountain pine beetle epidemic on site occupancy dynamics of > 60 avian species in four study units

dominated by ponderosa pine (*Pinus ponderosa*) in the Helena National Forest. Point count data were collected during the avian breeding seasons (May-Jul) of 2003-2006 (pre-epidemic) and again during 2009-2010 (post-epidemic). We used a Bayesian hierarchical model that accounts for detection probability to obtain occupancy estimates for rare and elusive species as well as common ones. We estimated occupancy and detection for all species with respect to the occurrence of the beetle outbreak, live tree density at fine scale (1 ha), and live tree density at coarse (landscape) scale (100 ha). Preliminary analyses focus on trends in occupancy for species of interest, such as the American Three-toed Woodpecker (*Picoides tridactylus*), as well as patterns of occupancy for nesting and foraging guilds. Results indicated diverse responses among species, with occupancy rates increasing for some and declining for others.

Using Genetics To Study Otter Connectivity And Population Size In Northwestern Montana

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River otters (*Lontra canadensis*) have begun to recover in the Upper Clark Fork River (UCFR) after decades of mining and smelting activity severely impacted the population. An initial project in 2009 showed otters occur throughout the UCFR but at seemingly lower densities than other rivers in Montana. We are working to estimate otter population size in the UCFR and determine connectivity between other geographically close rivers. We are using 11 microsatellite loci amplified from tissue samples collected from trapped otters to look at connectivity between 5 rivers: the Bitterroot River, Blackfoot River, Clearwater River, UCFR, and Lower Clark Fork River. We are using heterozygosity and Fst values to indicate population substructuring as well as using principle component analysis to visualize any differentiation. Additionally, we are using hair collected from hair snares to genetically estimate population size in the UCFR. Initial results from tissues indicate that otters in the 5 rivers are highly connected, and no one population is more connected to the UCFR than another. These results are based on a small samples size; additional samples currently being analyzed will enhance our ability to interpret this situation. Additional samples will be collected in 2011 to strengthen the population estimate. This is one of a few projects, and the first in Montana, to use genetics to look at population substructuring in otters.

Using Spatial Models To Map Bird Distributions Along The Madison River

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The Avian Science Center developed predictive maps of species distributions for the Madison River based on newly available riverine system data from the National Wetlands Inventory (NWI) and the Natural Heritage Program's Landscape Integrity Model. We used a maximum entropy model (MaxEnt) to predict species distributions using species occurrence locations collected from 2003-2010. Models performed well for 13 species, demonstrating that available environmental data layers, including NWI, can be used to successfully predict species distributions along the Madison River for a number of important riparian bird species. These models allow fine-scale mapping of habitat suitability for riparian birds, which fills gaps in current data on species distributions, and can be used to prioritize riparian conservation and restoration projects.

Something's Fishy: A Genetic Investigations Of Sculpin Species In Western Montana

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Sculpin (*Cottus* spp.) are small, cryptic, bottom-dwelling fish native to cool and coldwater systems throughout North America. Although three species of primarily stream-dwelling sculpin are thought to occur in Montana (one of which is a species of concern), their taxonomy, distribution, and origin are not well understood. In western Montana, the present distribution of sculpin species may have been shaped by both historical events, e.g., the Columbian Ice Sheet, and contemporary landscape changes (passage barriers, climate change, pollution, etc.). To evaluate sculpin presence, and species diversity, we analyzed sculpins from river drainages throughout western Montana—the Clark Fork, Blackfoot, Flathead, Bitterroot, Kootenai, Gallatin, Madison, and Missouri—east and west of the Continental Divide. We analyzed 135 samples at the mitochondrial DNA COXI gene and at 11 microsatellite DNA loci. Preliminary results of genetic analysis suggest the presence of four distinct species with hybridization among three of the species in some locations. Hybridization led to uncertainty in species designations based on morphology, but even genetically pure fish were occasionally misidentified. One species may represent an undescribed taxon that is limited in its distribution to the St. Regis drainage, although its relation to sculpin in Idaho is unknown. A second species, previously thought to be *Cottus bairdii*, is distinct from that taxon and is distributed on both sides of the Continental Divide.

Long-Term Effects Of Ponds, Climate, And Upland Habitats On Prairie-Nesting Ducks

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North American mid-continental breeding duck populations have historically demonstrated extreme annual variability, typically attributed to variation in annual spring

pond numbers. However, strengths of these relationships have not remained constant over time or space for some species. Possible explanations for changes in duck/pond associations include reduced quality of wetlands and reduced quantity or quality of upland habitats. Therefore, I hypothesized that changes in the associations between ducks and ponds could be attributed to spring precipitation, temperature, and upland habitats. I modeled observed duck numbers using random coefficient models structured to represent Gompertz population growth with environmental covariates. Varying modeled intercepts and slopes identified segment specific variation in carrying capacity and limiting environmental factors, respectively. I compared models of alternative a priori hypotheses describing duck abundances relative to various combinations of ponds, climate, and upland habitat using an information-theoretic approach.

Including additional climate and upland habitat covariates produced superior models to pond-only models when predicting duck abundances. Best models identified segment varying differences in the strengths of relationships between ducks and environmental covariates, implying spatial variability in factors limiting abundances. Top models were consistent with my hypothesis that climate and upland habitats provide additional information regarding duck population changes. Knowledge of important environmental covariates that improve spatio-temporal models provides waterfowl managers with opportunities to target management programs in areas with the greatest benefits, or to protect specific habitat components where they are most limiting. Identifying areas with different levels of population response can potentially identify interesting new explanatory variables.

Lead, Health and the Environment: Old Problem and 21st Century Challenge

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Conservation medicine examines the linkages among the health of people, animals and the environment. Few issues illustrate this approach better than an examination of lead (Pb) toxicity. Lead is cheap and there is a long tradition of its use. However the toxic effects of Pb have also been recognized for many years and our knowledge of the lethal and sublethal effects of Pb continues to grow dramatically. As a result, western societies have eliminated or greatly reduced many traditional uses of Pb, including many paints, gasoline and solders because of threats to the health of humans and the environment. Legislation in several countries has eliminated the use of lead shot for hunting waterfowl. Despite these advances, a great many Pb products continue to be readily available. Wildlife and environmental agencies recognize that angling and shooting sports deposit thousands of tons of Pb into the environment each year. Given what we are learning about the many toxic effects of this heavy metal, there is every reason to switch to non-toxic alternatives. To accomplish this, a broad, ecological vision is important. This presentation will briefly review the current state of knowledge on the toxicity of lead and its behavior in the environment, including the effects on wildlife, humans, and domestic animals. We will also discuss why wildlife professionals need to take a leadership role in bringing together all interest groups to find safe alternatives, to develop new educational and policy initiatives, to eliminate many current uses of Pb, and to clean up existing problems.

Literature Review And Synthesis Of The Effects Of Residential Development On Ungulate Winter Range In The Rocky Mountain West

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In the past 40 years human population and rural residential development at exurban densities have increased dramatically in the Rocky Mountain West resulting in increasing rates of conflict between high quality ungulate habitat and development. Roads and subdivisions near and in winter range affect ungulates in multiple ways and reduce management options. The literature review covered more than 100 articles on the effects of land use change, especially residential development at exurban densities, on five focal species; elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white tailed deer (*Odocoileus virginianus*), American pronghorn (*Antilocapra antilocapra*) and bighorn sheep (*Ovis canadensis*). The direct and indirect effects of exurban development on ungulate winter range vary by region, species, specific habitat type, development type, and human wildlife perceptions. Topics of particular interest included zone of human influence, minimum habitat patch size requirements, habituation, thresholds between functional and non-functional winter range, associated costs of exurban development, and cumulative effects. The literature sheds light on some of these issues, however, few studies addressed the impacts of land use change on population dynamics over the long term. For example, rigorous testing of the cumulative impact that multiple developments and development types, i.e., roads, housing, industrial development, have on seasonal habitat use and migratory behavior has been limited. Short-term and small-scale observational studies must be replaced by well designed experiments to help managers and planners make more credible recommendations to direct future exurban development.

Using Hunter Survey Data To Estimate Wolf Population Sizes In Montana, 2007-2009

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Reliable knowledge of the status and trend of carnivore populations is critical to their conservation. In the Northern Rocky Mountains, wildlife managers need a time- and cost-efficient method for monitoring the large, growing population of gray wolves (*Canis lupus*) at

a state-wide scale. We explored how hunter survey data could be incorporated into a multi-year patch occupancy model framework to estimate the abundance and distribution of wolf packs, wolves, and breeding pairs in Montana for 2007- 2009. We used hunter observations of wolves to estimate the probability that a given landscape patch was occupied by a wolf pack, and used additional data/models in combination with occupancy model output to provide estimates of total number of wolves and number of breeding pairs. Our modeling framework also allowed us to examine how geographic and ecological factors influenced occupancy and detection of wolf packs. Our models provided estimates of number of packs, number of wolves, and number of breeding pairs that were within 20 percent of Montana Fish, Wildlife, and Parks minimum counts for 2007-2009. We found occupancy was positively related to forest cover, rural roads, and elevation and detection probability was positively related to hunter effort and forest cover. We believe that patch occupancy models based on hunter surveys offer promise as a method for accurately monitoring elusive carnivores at state-wide scales in a time- and cost-efficient manner.

Factors Influencing Pika Foraging Behavior In The North Cascades National Park Service Complex, Washington

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The American pika (*Ochotona princeps*) is a small lagomorph restricted to talus slopes at higher elevations or latitudes throughout mountainous regions in western North America. Pikas respond to seasonal fluctuations in food availability by haying, i.e., storing, vegetation for use during winter, and are considered a climate change indicator species because of their sensitivity to heat and restricted habitat requirements. Prior to 2009, no data existed on pika populations or foraging behavior in the North Cascades National Park Service Complex (NOCA) in Washington. To help address these data needs, we collected behavioral data on 95 foraging pikas throughout NOCA during summer 2009 and 2010 to better understand abiotic and biotic factors affecting foraging behavior and potential impacts of climate change on pikas. We calculated the proportion of time pikas spent grazing and haying, and developed competing hypotheses for each behavior expressed as logistic regression models consisting of climate, vegetation, elevation, date, and year covariates. We selected top models for both behaviors using information-theoretic techniques, and found that time spent grazing decreased while haying behavior increased through summer. Pikas spent more time haying as elevation increased while time spent grazing was negatively correlated with elevation, suggesting possible constraints in time available for foraging at higher elevations. Time spent grazing was also negatively correlated with temperature, a result likely in response to thermoregulation limitations of pikas. These results demonstrate how multiple factors may affect pika foraging behavior, thereby providing an opportunity to assist resource managers in future decisions regarding pika conservation.

Survival And Mortality Of Mountain Lions In The Blackfoot Watershed, West-Central Montana

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We investigated population effects of harvest on mountain lions (*Puma concolor*) using a pseudo-experimental before-after-control-impact (BACI) design. We achieved this through 3 yrs of intensive harvest followed by a recovery period. In December 2000, after 3 yrs of hunting, approximately two-thirds of district 292 was closed to lion hunting, which effectively created a refuge, representing approximately 12 percent (915 km2) of the total Blackfoot watershed (7908 km2). Hunting continued in the remainder of the drainage, but harvest levels declined between 2001 and 2006 as quotas were reduced. From January 1998 and December 2006, a total of 121 individual mountain lions were captured, 152 times, including 82 kittens, and 39 juveniles and adults. Of these, 117 individuals were collared and monitored on average for 502 days (~ 16 mos) with males remaining on the air for shorter periods ($\bar{X}$ =284 days) than females ($\bar{X}$ =658 days). Hunting was the main cause of mortality for all age and sex classes across the study period, accounting for 36 of 63 mortalities documented. This was followed by illegal mortalities, natural, unknown, depredation, and vehicle collisions. Across the study period, any lion in the Blackfoot watershed had, on average, a 22 percent annual probability of dying due to hunting. We found human harvest to be an additive mortality source, i.e., hunting mortality was not compensated for by increased survival of remaining individuals that shapes the overall survival structure of mountain lion populations. As such, wildlife managers through the use of human harvest, have the capability to regulate mountain lion population growth.

Modifying Barrier Fences In Key Wildlife Linkages In Western Montana

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American Wildlands has identified landscape level wildlife linkages and corridors throughout western Montana and eastern Idaho. We are working cooperatively to implement on-the-ground projects to maintain or enhance this habitat connectivity. On a local scale, wildlife movement through these linkages is often impeded by livestock and property boundary fences. Fences with bottom wire spacing less than 16-18 in above ground level and taller than 40-42 in are usually barriers and entanglement hazards to deer, elk, bighorn sheep, and pronghorn, particularly for their young. BLM and Forest Service policy directs that public land fences will accommodate wildlife movement using wildlife-friendly fence specifications have been available for years, and some modification has been completed. But hundreds of miles of wildlife-unfriendly fences still exist throughout southwestern Montana on both private and public lands, and the miles are increasing. In 2008, American Wildlands initiated a fence modification program to cooperatively "fix" wildlife-unfriendly fences located in key wildlife linkages with emphasis on pronghorn movement. To date, nearly 50 mi of fence have been modified or reconstructed in the Centennial Valley, Grasshopper Valley, and East Pioneers, mostly on private lands and often using volunteer labor. Modification costs are minimal for simple wire adjustments or removal to achieve appropriate wire spacing, and represent little or no cost to the landowner. Although more expensive, modifying net wire fences can have dramatic benefits for wildlife movements.

Effects Of A Rest-Rotation Grazing System On Wintering Elk Distributions On The Wall Creek, Montana Winter Range

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Understanding livestock grazing effects on wildlife remains an important conservation issue. The purpose of this project was to evaluate the effects of a rest-rotation grazing system on elk resource selection within the Wall Creek winter range in southwest Montana. We collected bi-weekly observations of elk (*Cervus elaphus*) number and distributions across the winter range from 1988-2007. Using a matched-case control logistic regression model to estimate selection coefficients, we evaluated the effects of annual green-up conditions, winter conditions, landscape features, and grazing treatment on elk resource selection within the grazing system. We found that within the grazing system, elk preferentially selected for rested pastures over pastures that were grazed the previous summer. The strength of selection against the pasture grazed during the growing season was strongest, and pastures grazed during the early and late summer were selected for over the pasture grazed during the growing season. The number of elk utilizing the grazing system increased in the 19 years following implementation of the grazing system; however, total elk herd size also increased during this time. We found no evidence that the proportion of the elk herd utilizing the grazing system changed following implementation of the rest-rotation grazing system. Our results provide support for the principals of rest-rotation grazing systems. Wintering elk preference for rested pastures suggests rested pastures play an important role in rotation grazing systems by conserving forage for wintering elk. We recommend wildlife managers maintain rested pastures within rotation grazing systems existing on ungulate winter range.

Adaptive Wolf Management: The Regulated Public Harvest Component

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Montana's wolf (*Canis lupus*) conservation and management plan is based on adaptive management principles and includes regulated public harvest as a population management tool. The need and opportunity to implement public harvest in 2008, 2009, and 2010 required Montana Fish, Wildlife and Parks (FWP) to develop a stepped down adaptive management framework specific to harvest. For 2008 and 2009, FWP set modest objectives: implement a harvest, maintain a recovered population, and begin the learning process to inform development of future hunting regulations and quotas. In 2010, FWP used a formal Structured Decision Making Process to more clearly define priorities and challenges of setting a wolf season, outline objectives of a successful season, and evaluate consequences and trade-offs between alternative management actions. For all years, FWP used a modeling process to simulate a wide range of harvest rates across three harvest units and to predict harvest effects on the minimum number of wolves, packs and breeding pairs. Model inputs were derived from minimum wolf numbers observed in the field. Modeling allowed consideration of a range of harvest quotas, predicted outcomes, and risk that harvest could drive the population below federally-required minimums. It also facilitated explicit consideration of how well a particular quota achieved objectives and how to adapt future regulations and quotas. Legal challenges to federal delisting restricted implementation of the first fair chase hunting season to 2009. Montana's wolf population is securely recovered, despite the dynamic political and legal environments. Regardless, FWP remains committed to a scientific, data-driven approach to adaptive management.

Habitat Quality Influences Bird Community Structure In The Big Hole River Valley

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Extensive restoration work along the Big Hole River aims at improving habitat conditions for the last remaining fluvial population of Arctic grayling (*Thymallus arcticus*) in the U.S. Riparian-associated birds are also likely to respond positively to such restoration activities. From 2007 to 2009 we conducted surveys to document bird communities during the pre-restoration phase. We detected 111 species across the three survey years, representing 45 percent of bird species known to breed in Montana. We used a repeated measures design to control for potential variation in relative bird abundance among years and to test for differences among three treatment types: reference, control, and restoration. Both vegetation characteristics and bird communities differed significantly among treatments. Eight species selected a priori to be indicators of high quality riparian habitat were significantly more abundant at reference points than at control or restoration points. These species will be used as indicators to measure the success of restoration efforts in the future. The outstanding diversity of birds associated with the Big Hole watershed speaks to the conservation value of restoring this stretch for birds as well as fish.

Synthesizing Moose Management, Monitoring, Past Research, And Future Research Needs In Montana

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Perceived declines in Shiras moose (*Alces alces shirasi*) in many areas across Montana in recent years have elicited concern from biologists, managers, and members of the public. Interest in moose research in Montana has correspondingly been mounting, however little new research has occurred. For this reason we attempted to synthesize existing knowledge and management programs for moose in Montana to provide collective awareness of the issues and research needs for moose. We used structured interviews of wildlife biologists and managers that work with moose to document current moose management in Montana. Most biologists reported that moose were stable or decreasing in their areas of responsibility. Predation was the most common concern for factors limiting moose, followed by habitat succession, hunter harvest, disease and parasites, Native American harvest, and habitat loss, fragmentation and degradation. In addition to information from post-season surveys of moose permit holders, biologists assessed moose populations using information from a variety of sources including landowner reports, hunter reports collected at check stations, unadjusted trend counts, bull: cow ratios, recruitment ratios, sightability-corrected population estimates and habitat condition. Nearly all respondents felt that available information was inadequate in various ways for making moose management decisions. Clearly identified research needs include calibration of currently employed moose population indices to actual trends in moose

populations, development of a survey program that will provide better and more moose survey data at the appropriate scale for management decisions, and research into how predation, habitat, disease, parasites, and climate affect moose survival and recruitment rates.

Mercury Magnification In Riverine Food Webs In The Northern Rocky Mountains: Clark Fork River Basin, Montana, U.S.A.

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At a local scale, such as the Clark Fork River Basin (CFRB), historic gold mining contributes the majority of mercury (Hg) found in the environment. Mercury enters aquatic systems in inorganic forms and is transformed to methylmercury (MeHg) by bacteria. MeHg has the ability to bioaccumulate within higher trophic levels, causing severe neurotoxic diseases and mortality. Hg concentrations observed within an aquatic food web are controlled by two factors, a source of inorganic mercury and the potential for that Hg to become methylated (methylation controlled by environmental conditions i.e.: water velocity, organic matter, etc.). A sufficient source of inorganic mercury and environmental conditions which promote Hg methylation can lead to maximum MeHg biomagnification. This study presents a comprehensive look at food web Hg biomagnification within the CFRB. Hg concentrations are characterized through blood or tissue samples from osprey, fish, and aquatic macroinvertebrates. Additionally we look at controlling Hg biomagnification factors, Hg of fine-grained sediment, percentage of wetlands and riparian land cover, and mean monthly discharge, to access the biomagnification process within the watershed and thus the Hg levels observed throughout these three trophic levels. Preliminary results show Hg levels of aquatic invertebrates have been found to be heavily influenced by the source of Hg (fine-grained sediment), while upper trophic level species exhibit a strong correlation to environmental characteristics of the sample reach.

Temporary Emigration Of Female Weddell Seals Prior To First Reproduction

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Temporary emigration (TE) from a breeding site is common in some colonial-breeding species, but implications are poorly understood because TE is difficult to quantify. We used capture-mark-recapture models and a dataset of 5450 female Weddell seals (*Leptonychotes weddellii*) born in Erebus Bay, Antarctica to investigate sources of variation in TE rates and evaluate possible implications for recruitment. Temporary emigration rates and recruitment rates were state- and age-dependent and annually variable. For seals that attended reproductive colonies the previous year, mean TE rates decreased from 0.98 (sd = 0.02) at

age 1 to 0.15 (sd = 0.16) at age 8, whereas mean recruitment rates increased from 0.06 (sd = 0.03) at age 5 to 0.52 (sd= 0.16) at age 10. Seals that did not attend reproductive colonies the previous year had greater TE rates and lower recruitment rates than seals that did attend colonies, but the confidence interval for the effect of TE on recruitment included zero. Our results suggest that 1) motivation to emigrate varies temporally depending on environmental conditions, 2) as seals grow older they have increased motivation to attend reproductive colonies even before they are ready to recruit, and 3) some seals appear to always be more likely than others to emigrate. We suspect that TE may allow seals to buffer variability in survival rates.

Black Bear Density In Glacier National Park, Montana

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No demographic information exists on the status of Glacier National Park's (GNP) black bear (*Ursus americanus*) population. In 2004, we sampled the black bear population within GNP plus a 10 km buffer using noninvasive hair collection methods as part of a 7.8 million–acre study of the regional grizzly bear (*U. arctos*) population. We collected 5645 hair samples from 550 baited hair traps, and 3807 samples from multiple visits to 1,542 natural bear rubs. Microsatellite analysis identified 601 (51% F) individuals from the 2848 samples identified as black bears. Data from individual bears were used in closed population mark–recapture models to estimate black bear population abundance. We developed an information-theoretic approach to estimate the effectively sampled area from which we calculated density for the 6600 km2 greater GNP area. Preliminary results suggest that the density of GNP's black bear population was equal to or greater than other interior populations sympatric with grizzlies, despite the high density of grizzlies. This project represents the first estimate of black bear density for this area, and demonstrates the efficiency of multi–species projects to inform management.

Managing Multiple Vital Rates To Maximize Greater Sage Grouse Population Growth

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Despite decades of greater sage grouse (*Centrocercus urophasianus*) field research, the resulting range-wide demographic data has yet to be synthesized into sensitivity analyses to guide management actions. We summarized range-wide demographic rates from 71 studies from 1938-2008 to better understand greater sage-grouse population dynamics. We used data from 38 of these studies with suitable data to parameterize a two-stage, female-based population matrix model. We conducted analytical sensitivity, elasticity, and variance-stabilized sensitivity analyses to identify the contribution of each vital rate to population growth rate (λ) and life-stage simulation analysis (LSA) to determine the proportion of variation in λ accounted for by each vital rate. Greater sage grouse showed marked annual and geographic variation in multiple vital rates. Sensitivity analyses suggest that, in contrast to most other North American galliforms, female survival is as important for population growth as chick survival and more important than nest success. In lieu of quantitative data on factors driving local populations, we recommend that management efforts for sage grouse focus on increasing juvenile, yearling, and adult female survival by restoring intact sagebrush landscapes, reducing persistent sources of mortality, and eliminating anthropogenic habitat features that subsidize predators. Our analysis also supports efforts to increase chick survival and nest success by managing shrub, forb, and grass cover and height to meet published brood-rearing and nesting habitat guidelines, but not at the expense of reducing shrub cover and height below that required for survival in fall and winter.

The Decline And Isolation Of Fisher Populations Prior To European Settlement: Insights From Dna Analysis

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Historical and contemporary genetic information can provide insights into the nature of population expansions or contractions and temporal changes in abundance and connectivity. Fisher (*Martes pennanti*) populations in California are thought to have declined precipitously over the last 150 yrs and currently only two populations remain in the state that are both geographically and genetically isolated from each other. In this study we looked at whether the isolation of these two populations is a result habitat alteration and trapping that accompanied European settlement in the mid-1800s or if it is the result of a more ancient demographic event. We collected both historical and contemporary genetic samples from each of the two extant fisher populations. We successfully obtained microsatellite genotypes at 10 loci for 21 museum specimens (dated 1882-1920) and 275 contemporary individuals (2006-2009). We found significant temporal shifts in allele frequencies between historical and contemporary samples between regions indicating large amounts of genetic drift likely due to isolation and small population size. We found a strong genetic signal for a 90 percent contraction in effective population size of fisher and estimated that this decline occurred over a thousand years ago. As a decline in abundance of this magnitude likely resulted in contraction of the geographic range, our analyses suggest that fisher populations in California became isolated from one another far prior to the European settlement of the state.

Hoary Marmot, White-Tailed Ptarmigan And Pika Surveys In Northwest Montana

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Montana Fish, Wildlife and Parks has long done survey and inventory of game species and largely within the past few decades has expanded the staff and program necessary to monitor non-game species, too. However, to date there has been little work done on three alpine species likely to be adversely impacted by climate change: the hoary marmot (*Marmota caligata*), white-tailed ptarmigan (*Lagopus leucurus*) and pika (*Ochotona princeps*). Prior to the 2010 field season, Montana Natural Heritage Program had only 31 hoary marmot, eight white-tailed ptarmigan, and 62 pika observations for northwest Montana outside of Glacier National Park. We discuss the beginning of focused survey and inventory effort for these three species in northwest Montana that include searching historical narratives, reaching out to other agencies and backcountry users, developing a species identification guide and sighting log for free distribution, and on-the-ground surveys. On one 4-day backpacking trip we saw or saw sign of 17 marmots in five "colonies" or local areas, 20 pikas and one ptarmigan as well as several other species. In addition to the current survey and inventory work we are outlining future more in-depth work including structured systematic surveys, future monitoring, research on marmot genetics and colony relatedness across the species range in Montana, and potential partners. We also discuss some new and novel approaches such as winter helicopter surveys and fecal DNA analysis for ptarmigan.

Moose Distribution And Age And Sex Ratios In Northwest Montana As Reported By Hunters At Check Stations

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We sought to better document moose (*Alces alces*) distribution and age and sex ratios in northwest Montana by asking hunters. During the 2010 hunting season we asked all hunters stopping at six check stations if they had seen moose, and if so, where, how many, and if they saw bulls, cows or calves. During the 13 days that check stations were open 17,564 hunters reported 490 sightings totaling 749 moose (313 bulls, 320 cows, 95 calves and 21 unknown) for an average of 1.5 moose per sighting (range 1 - 5). Across all check stations there was an average of 2.8 sightings and 4.3 moose seen per 100 hunters, but this varied from 0.9 sightings and 1.2 moose per 100 hunters at the Swan Check Station to 6.9 sightings and 10.4 moose per 100 hunters at Canoe Gulch. The bulls per 100 cows ratio averaged 98:100 across all check stations but varied from 67:100 at Canoe Gulch to 225:100 at the Swan. Likewise,

the calves per 100 cows ratio averaged 30:100 but varied from 8:100 at the Swan to 54:100 at Thompson Falls. Hunter-reported sex and age ratios at the North Fork Check Station agreed with those observed during a post-season helicopter survey in the same area ($\chi 2$ $p = 0.83$), but hunter-reported ratios at Olney were significantly higher than those observed by helicopter ($\chi 2$ $p = 0.01$). We discuss the difficulty of monitoring moose populations and the pros and cons of helicopter surveys and hunter-reported moose sightings.

Conserving Montana's Birds And Their Habitats Through Partnerships

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The Montana Bird Conservation Partnership is a consortium of representatives from state, tribal, and federal agencies, non-governmental organizations, and individuals who are dedicated to conserving birds and their habitats in Montana. Our goals are to work collaboratively to keep common birds common and to conserve, protect and restore sensitive species and habitats. We work to recognize the social and economic value of birds to the people of Montana. We also use the best available science to identify conservation opportunities. Over 300 species of birds regularly breed, winter, or migrate through Montana. Of these, 82 are considered to have sensitive or at-risk populations. Montana's birds are threatened by habitat loss stemming from changing land use practices and energy and subdivision development. Global climate change may exacerbate these threats. We will present current Montana Bird Conservation Partnership projects, our action plan, focal species initiatives, and examples of successful conservation-in-action projects. Find out how you and/or your organization can get involved at the local or state level. Learn more about the most exciting and forward-thinking bird partnership in the region!

Broad-Scale Genetic And Compositional Monitoring Of Aquatic Vertebrate Populations: A Proof Of Concept In The Interior Columbia River And Upper Missouri River Basins

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Monitoring fish and amphibian populations is essential for evaluating conservation efforts and the status and trends of individual species, but measuring abundance is time-consuming and problematic at large scales. Also, relations between fish populations and their surrogates, such as habitat characteristics, are often obscure. As an alternative, genetic assessment and monitoring offers promise as an indicator of population status and trends by providing information on genetic diversity, connectivity among populations, and the prevalence of hybridization with non-native species. We have undertaken intensive sampling of native and nonnative fishes and amphibians in streams monitored by the Pacfish/Infish Biological Opinion Monitoring Program, which includes a spatially comprehensive, random sample of subbasins in the interior Columbia River Basin and upper Missouri River Basin. We have also developed a panel of ~100 single nucleotide polymorphism markers for cutthroat trout, redband trout, and rainbow trout to describe patterns of hybridization and landscape genetic structure. If fully realized, analyses of tissues sampled from over 1500 streams in Montana, Idaho, eastern Oregon, and eastern Washington on federal lands should permit broad-scale evaluations of the status and distribution of much of the aquatic vertebrate fauna and enable detection of responses to climate change. Preliminary results of sampling at nearly 700 sites on almost 300 western Montana and northern Idaho streams indicate that westslope cutthroat trout occupy headwater sites in most of their historical range except in the Kootenai and Missouri River basins, brook trout are more widely distributed than previously recognized, and the taxonomic complexity of sculpins is underappreciated.

Adult Female Survival In A Partially Migratory Elk Herd

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Partial migration occurs when a portion of the population migrates, and results from density-dependence in the relative costs and benefits of migrating or remaining a resident. For elk (*Cervus elaphus*), partial migration is an adaptive strategy for maximizing optimum forage quality while reducing predation risk. I tested related hypotheses about the effects of migration status, season (summer, winter) and density on the winter range for adult female elk survival. I first tested whether migrants had higher survival, based on the hypothesized forage benefits of migration. Next, I tested the hypothesis that survival of adult female migrant and resident elk differs over time first, as a function of density and second, as a function of seasonal variation between summer and winter. I estimated survival for 204 radio-collared elk over 8 yrs using the non-parametric Kaplan Meier (KM) approach and regressed survival estimates against population size. I tested my hypotheses regarding season, migratory status, and density using the semi-parametric Cox-Proportional Hazards (PH) Model. I found weak evidence supporting my hypothesis that adult female survival is higher for migrant elk compared to resident elk. Migrants had twice the variation in survival rates and a greater risk of death during summer compared to residents. I observed strong evidence of density dependence from the Cox PH model and my regression of KM survival estimates for residents showed adult female survival decreased with increasing elk density over time. My results show preliminary evidence for density dependence affecting resident, not migrant, adult female elk in this population.

The Influence Of Conifers And Abiotic Factors On Big Sagebrush Cover

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Expansion of conifers into sagebrush is a concern since it reduces sagebrush cover for wildlife. The objective of this study was to model the relationship between the cover of Douglas-fir (*Pseudosuga menziesii*) and Rocky Mountain juniper (*Juniperus scopulorum*), and the cover of Wyoming big sagebrush (*Artemisia tridentate* spp. Wyomingensis) and mountain big sagebrush (*Artemisia tridentate* spp. *Vaseyana*). Two

hundred forty 30x30 m plots were established at three locations in southwest Montana in 2009 to establish this relationship. The best-fit model using AIC criteria found $\left(\sqrt{sagebrush\ \text{cov}er} = Intercept_{i\_} - 0.401\sqrt{conifer\ \text{cov}er}\ ; R^2 = 0.61\right)$ a negative relationship between conifer cover and sagebrush cover. No abiotic factors (elevation, slope, aspect, soil depth, soil texture and percent rock) significantly influenced sagebrush cover. Douglas-fir trees were found to have three-times the canopy area of similar aged Rocky Mountain juniper trees. Conifer removal to increase sagebrush cover is not recommended, since the increase in sagebrush cover is small. If conifer control is deemed necessary, Douglas-fir should be removed before Rocky Mountain juniper, and begin at low levels of conifer cover.

The Suitability Of Large Culverts As Crossing Structures For Deer

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Most researchers that have investigated the use of wildlife crossing structures have done so through counting the number of animals present in the structures or the number of animals that crossed the road using the structures. However, we argue that crossing structure acceptance, as a percentage of all approaches, is a better measure of suitability. Once the acceptance of certain types and dimensions of crossing structures is known for different wildlife species, agencies can select crossing structures that meet certain goals. We used this method for one particular type of crossing structure; large diameter culverts. We placed wildlife cameras (Reconyx™) at the entrance of nine corrugated metal arched culverts located along US Highway 93 on the Flathead Indian Reservation, Montana; to capture approach behavior. We specifically examined the number of successful and aborted crossing attempts. White-tailed and mule deer were the most frequently observed species and had an acceptance rate of 84 percent (n = 455) and 66 percent (n = 56) respectively. Only 49 percent (n = 426) of the groups that passed the structures successfully showed an alert posture versus 93 percent (n = 98) for the groups that aborted the attempts. The two deer species showed slightly different levels of alertness with an alert posture for 55 percent of white-tailed deer (*Odocoileus virginianus*) events and 68 percent for mule deer (*O. hemionus*)events for all crossing attempts combined. The data show that wildlife acceptance rates and behavior at structures can vary between species and data on varying structure type and dimensions will add to our understanding of structure acceptability for various target species.

Variation In Weddell Seal Pup Mass: Maternal Investment In Offspring

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Life history theory predicts that individuals face physiological tradeoffs between current and future reproduction. These tradeoffs ultimately lead to reproductive costs which can affect survival, fecundity, condition of the female and offspring survival. Reproduction itself is costly and involves a number of sequential physiological processes that require different levels of energetic investment. In mammalian species gestation and lactation require the most energy and energy expenditure during these times is a characteristic of females and can vary among individuals. Mass measurements, used to quantify pre- and post-partum maternal investment, were collected from 887 Weddell seal (*Leptonychotes weddellii*) pups at parturition and throughout lactation in Erebus Bay, Antarctica during the 2002 through 2010 field seasons. Preliminary analysis demonstrated high individual variation in pup mass within a season and modest variation among seasons suggesting that pup mass may be affected more by individual animal attributes than annual variation in environmental conditions. This variation in maternal investment was investigated using maternal traits taken from the long term database. We found that maternal traits have different affects on pup mass at different stages of investment. Maternal age and birth date were found to be influential on pre- and post-partum investment along with age at first reproduction on pre-natal investment and breeding status the previous year on post-natal investment. The variation in the influence of maternal traits on maternal investment may be due to the increased energy requirement of lactation and reproductive costs that females accrue throughout their lifetime.

Evaluating The Barrier Effect Of A Major Highway On Movement And Gene Flow Of The Northern Flying Squirrel

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Roads are pervasive sources of habitat fragmentation around the world, affecting an estimated 19 percent of the land area of the coterminous United States (Forman 2000). The barrier effect of roads has been demonstrated for species from multiple taxa. Still, information regarding the response of the vast majority of species to roads is lacking. We examine the effects of a major roadway on the movement and population genetics of Northern flying squirrels (*Glaucomys sabrinus*) in the Cascade Mountains of Washington, USA. During 2009 and 2010, flying squirrels (n = 16) were trapped and radio-tracked to gather data on movement within their home ranges and to detect movement across the roadway. Additionally,

DNA was extracted from cheek cells of 41 individuals and genotyped at 12 microsatellite loci to characterize patterns of population structure. Seven of 16 monitored squirrels crossed the highway at least once during their nightly movements. Randomization tests of the movement data do not indicate significant avoidance of crossing the highway corridor. Movement does not necessarily equate to gene flow, however, and forthcoming analysis of microsatellite data will help elucidate whether current rates of movement are sufficient to maintain genetic connectivity across the highway.

50-Year Golden Eagle Nesting Trends In South-Central Montana

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Golden Eagle (*Aquila chrysaetos*) migration counts in the western North America have shown a significant negative trend in recent years. However, the causes of these declines are unknown and it remains unclear if declining migration counts correlate to a declining population or changes in migratory behavior. Long-term research on nesting Golden Eagle populations is lacking and is needed to properly assess the current Golden Eagle population status in many areas. In 1962, intensive monitoring efforts were initiated in a roughly 1200-mi2 study area in south-central Montana. The objectives were, among other things, to determine density and productivity of Golden Eagles. This area was re-surveyed in the mid 1990s to begin looking at long-term population trends. In 2009, we initiated a multi-year effort to investigate potential changes in the nesting trends in the same study area over a half a century. The data collected to date indicate an increase in the nesting density, similar nest success rates, and a decrease in productivity when compared with both the 1960's and 1990s studies. The longevity of data collected in this study area allows for one of the longest-term comparisons for Golden Eagle nesting density and success in the West and provides invaluable insights into the status of nesting Golden Eagles in this region.

Keeping Common Species Common: Inventory And Monitoring For A Diversity Of Wildlife Species

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Many of the over 500 vertebrate species found in Montana lack formal status assessments. Few monitoring efforts exist for these species and very few are statewide to include public and private lands. In 2008, the Montana Natural Heritage Program and Montana Fish, Wildlife and Parks designed a protocol for simultaneous multi-species survey. We sampled quarter-quadrangle grid cells selected at random over 3 yrs and covered the entire state. We surveyed all lentic sites for amphibians and all south-facing rocky slopes for reptiles within each cell. We also surveyed dominant habitats for bats using acoustic detectors

and small-mammals using standard trap line techniques. The largest challenges included: securing private landowner contact information and permission, automating map creation for the hundreds of selected cells, the preservation of collected specimens, maintaining working acoustic equipment in inclement weather, housing and backing up huge amounts of data from remote locations, and analyzing large quantities of acoustic data. Small mammal and acoustic call identifications are ongoing. A preliminary summary of other data shows an investment of over 20,000 person hours for a total of: 211 grid cells surveyed, 40 small mammal species detected in 2486 captures, 16 bat species detected through thousands of acoustic calls, 12 amphibian species and eight reptile species detected, and 304 species detected as incidental observations. We intend to conduct occupancy modeling for many of the species detected using the grid cells as site. We discuss prospects for using this sampling scheme and methods for future monitoring.

Use Of Wildlife Crossing Structures On Us Highway 93 On The Flathead Indian Reservation

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In the 1990s, Montana Department of Transportation (MDT) proposed an expansion of U.S. Highway 93, in an area entirely within the Flathead Indian Reservation (FIR), home to the Confederated Salish and Kootenai Tribes (CSKT). In December 2000, the CSKT, MDT, and Federal Highway Administration (FHWA) signed a memorandum of agreement that enabled its expansion. It included wildlife mitigation measures to both mitigate impacts to wildlife and natural processes associated with the widening of US93 as well as to address the safety of the traveling public. Mitigation measures include 41 fish and wildlife-crossing structures, including 40 underpasses and one overpass, wildlife fencing, jumpouts, and wildlife crossing guards across 56 mi of highway. Crossing structures were placed in areas that have a history of wildlife crossings and wildlife mortality, and/or locations where the surrounding landscape and land use was best suited for the crossing structures. Research is underway to determine the effectiveness of the mitigation (see www.mdt.mt.gov/research/projects/env/wildlife_crossing.shtml). Between May 2008 and December 2009, eleven underpasses were monitored for wildlife use. Wildlife use of the structures was substantial with 3,000 deer crossings, 1500 coyote crossings, 300 bobcat crossings, 200 raccoon crossings, and 200 black bear crossings. Other species that used the crossings include mountain lion, elk, grizzly bear, moose, badger, river otter, muskrat, beaver, skunk, rabbit, and various bird species. For the wildlife mitigation measures to be considered successful, goals have been set by the CSKT, MDT, and FHWA, and more data need to be collected and analyzed before the researchers can conclude whether the mitigation measures have indeed reached those goals.

Sentinel Plant Species – Lookouts For The Land

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Sentinel plant species are first to vanish with change to the evolutionary concert of ecological processes playing in a locale. The evolutionary concert of ecological processes is the combination of fire, hydrology, herbivory, and predation under which local flora and fauna first evolved. If first to vanish plant species populations are viable, other plant and animal species populations are likely to be viable also. Sentinels are lookouts for the beginning unraveling of connectivity within landscapes. Large recovery of ecological systems is linked with small recuperations of sentinel well being. Restoration of sentinels may be accomplished by the return of an evolutionary course of management. Sentinel plant species monitoring and management is not based on vegetation classification systems such as the National Vegetation Classification System or Ecological Site Classification. Classifications often do not change with the disappearance of management sensitive uncommon species (sentinel plants). Major declines in sentinel plant species critical to specific wildlife species can occur before classification systems will notice. Monitoring consists of demographic measurements of sentinel species at randomly selected locations. Resource selection modeling of these ‘used’ and of “unused’ locations may be accomplished with the demographic measurements and GIS layers such as soils, topography, and management history. The purpose of the modeling is to predict the presence and health of the species, as a function of management, using statistical methods like logistic regression.

Determining Sex In Golden Eagles Using Foot Displacement

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The Golden Eagle (*Aquila chysaetos*) is one of the most widespread raptors in the world. Attempts have been made in the past to determine sex in Golden Eagles (GOEA) through individual and combined morphometric measurements. Due to the gender overlap within these measurements, the GOEA is one of several diurnal raptor species in North America that cannot be conclusively sexed in the hand. Sex in GOEAs is currently determined only through DNA analysis. Determining sex in the hand would increase the value of information collected by banders in the field, unable to devote time or resources to conduct blood or tissue assays. David Ellis, the author of the GOEA monograph, has developed an instrument under the assumption that foot volume could be definably different between male and female GOEA’s. This method measures the volume of the eagle’s foot, hallux claws, and lower part of the tarsus by the amount of water (cc) displaced. The technique is in its infancy and will be refined as needed. Since 2008, Raptor View Research Institute (RVRI) has measured foot displacement on 36 GOEAs captured on migration in Montana. Our preliminary data shows a 3 cc separation in foot displacement between male and female GOEAs.

Montana's Colonial Nesting Waterbird Survey

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Wetlands are a dispersed but declining resource in Montana. They are considered a Tier 1 community (greatest conservation need) in Montana's Comprehensive Fish and Wildlife Conservation Strategy and are of critical importance to breeding waterbirds. Of the 17 colonially-nesting waterbirds in the state, 12 are Montana Species of Concern. Despite the conservation ranking of waterbirds and their habitats, information on the distribution and abundance of these wetland obligates is limited. The Montana Bird Conservation Partnership is participating in the USDI Fish and Wildlife Service west-wide colonial nesting waterbird inventory to contribute to regional population estimates and meet state information needs. We are focusing on Species of Concern. We counted nests at 123 wetland sites across the state in 2009 and at 133 sites in 2010. Colony size ranged from 1-4833 pairs. Most colonies were relatively small (1-195 pairs), except Franklin's Gulls and American White Pelicans. High water levels likely affected reproductive success in spring 2010. Additional survey work will be conducted in 2011. In addition to calculating estimates of population size, we plan to use these data, in conjunction with other work, to link waterbird populations to wetland condition for use in future conservation decisions and planning. Our work has particular relevance to predicted changes in timing and amount of precipitation associated with climate change, which will likely change wetland condition and distribution throughout the state.

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