# Intermountain Journal of Sciences

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IJS

# 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.

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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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# Intermountain Journal of Sciences

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

| | | |
|---|---|---|
| | **Balance 01/01/12** | **$1,844.24** |
| **Income:** | | |
| | Subscriptions: | |
| | Regular Member | $60.00 |
| | Student Member | $6.00 |
| | Life Member | $150.00 |
| | Library Subscriptions | $250.00 |
| | International Member | $25.00 |
| | **Subscriptions Total** | **$491.00** |
| | Page Charges | $3,860.00 |
| | Reprints | $588.00 |
| | Back Issue Sales | $10.00 |
| | **Total Income** | **$4,949.00** |
| **Expenses:** | | |
| | Design and Printing | $3,679.40 |
| | Postage | $183.39 |
| | P. O. Box Rent | $120.00 |
| | Administrative and Bank Fees | $114.30 |
| | Reprints and Layout | $671.00 |
| | Website Maintenance | $171.78 |
| | Storage | $346.00 |
| | **Total Expenses** | **$5,285.87** |
| | **Balance 12/31/12** | **$1,507.37** |

*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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# *Navicula whitefishensis*, a New Diatom (Bacillariophyta) From the Northern Rockies

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## Abstract

*Navicula whitefishensis* is described from two headwater lakes in the Northern Rocky Mountains of Montana. The new species is compared to two morphologically similar species that are common in the region: *Navicula triviali*s Lange-Bertalot and *Navicula oligotraphenta* Lange-Bertalot & Hofmann. *Navicula whitefishensis* is the eleventh new species in the genus *Navicula* to be described from the Northwest United States within the last year. All of these new species are local or regional endemics.

**Key words:** *Navicula trivialis*, *Navicula oligotraphenta*, *Navicula*, Northwest United States, Northern Rocky Mountains, Montana, diatoms, endemic species, biodiversity

## Introduction

Diatoms are photosynthetic eukaryotic microbes distinguished by cell walls composed of silica. Diatoms are ubiquitous in aquatic habitats, where they are important primary producers and consumers of carbon dioxide. Diatoms are useful in biomonitoring and, as fossils in lake sediments, in reconstructing past climates and lake environments. With an estimated 200,000 species worldwide, diatoms are an important component of global biodiversity (Smol & Stoermer 2010, Seckbach & Kociolek 2011).

With only about 24,000 species already described, the bulk of the world's diatom flora remains uncatalogued. The Northwest is perhaps the most remote and undeveloped quarter of the contiguous United States and among the last regions in the country to be explored for diatoms. About 1500 diatom species have been reported from the region, including 209 species of *Navicula*, the region's largest genus (Bahls 2009). Recent studies have described over 30 new species from the Northwest, including 10 new species assigned to *Navicula* (Bahls 2011, 2012). All of these new species are local or regional endemics.

## Methods and materials

Samples were collected from two oligotrophic lakes in the Canadian Rockies Ecoregion (USEPA 2000) of northwestern Montana. The region features higher elevations and higher precipitation than adjacent areas of the Northern Rockies. The prevailing rock types are argillites and quartzites. Lakes in the region are typically fed by glacier meltwater and have circumneutral pH and low conductivity. Specific conductance and pH were measured in the field with a Hanna Instruments waterproof meter, model 98129.

Composite diatom samples were collected from available substrates (rocks, sediment, and/or vegetation) using a tablespoon or a large-bore pipette with suction bulb. Samples were preserved with Lugols (IKI) solution before transport to the laboratory, where they were treated with concentrated sulfuric acid ($H_2SO_4$), potassium dichromate ($K_2Cr_2O_7$), and hydrogen peroxide ($H_2O_2$) to remove organic matter (American Public Health Association *et al.* 1992). After several rinses in distilled water, cleaned diatom material was mounted permanently on microslides using Naphrax and examined under a Leica DM LB2 light microscope (LM) with differential interference contrast optics and equipped with a Spot Insight Model 14.0 monochrome digital camera. Measurements were made from digital images using Spot Software (version 4.5). Slides and cleaned material from these samples have been deposited in the Montana Diatom Collection (MDC) in Helena and duplicate slides (when available) have been deposited in the University of Montana Herbarium (MONTU) in Missoula: (http://herbarium.dbs.umt.edu/diatoms.asp).

## New Species Description

Division **Bacillariophyta**
Class **Bacillariophyceae** Haeckel 1878 *emend.* D. G. Mann in Round *et al.* 1990
Subclass **Bacillariophycidae** D. G. Mann in Round *et al*. 1990
Order **Naviculales** Bessey 1907
Family **Naviculaceae** Kützing 1844
Genus ***Navicula*** Bory de Saint-Vincent 1822
***Navicula whitefishensis* Bahls, *sp. nov.*** (Figures 1–5)

### Description

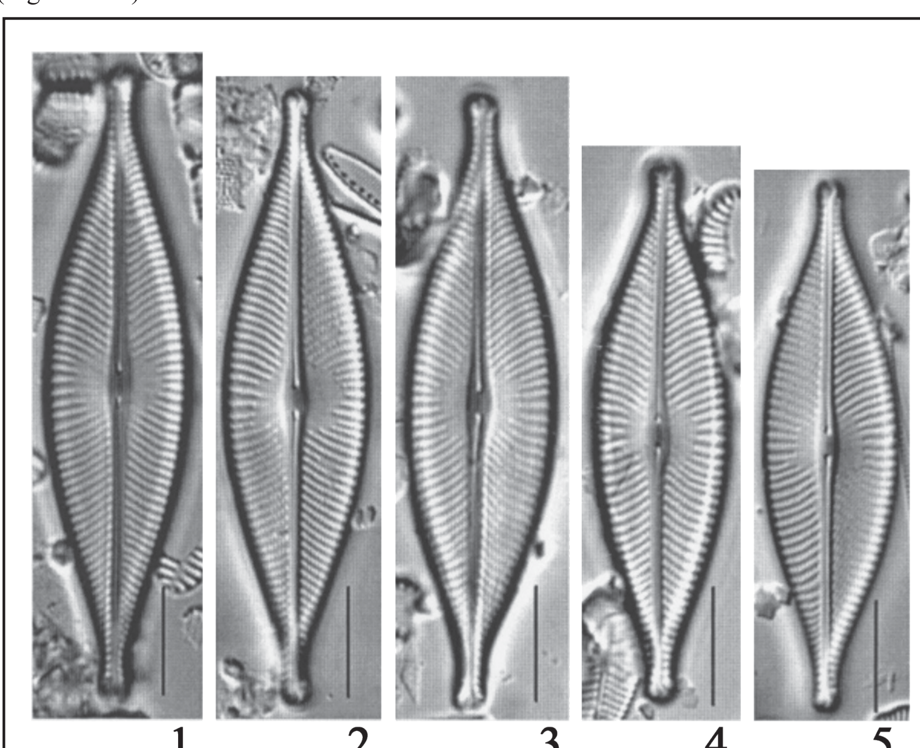
Valves broadly lanceolate with abruptly protracted and narrow subcapitate apices. Length 46-60 µm, width 11.3-14.2 µm. Axial area narrow, gradually widening toward a very large, rounded central area. Central area 5.9-8.2 µm in diameter. Raphe filiform to weakly lateral. Proximal raphe ends relatively distant, expanded and weakly deflected to one side. Terminal raphe fissures curved, opening toward the secondary side. Lineolate striae radiate almost throughout, becoming parallel then convergent only very near the poles, 12-14 in 10 µm. Areolae rather indistinct under LM, 28-30 in 10 µm.

### Holotype

Here designated as circled specimen on slide MDC P3-24-8. Holotype specimen illustrated in Fig. 1.

### Holotype locality

Upper Whitefish Lake, Flathead County, Montana, USA. 48.687° N, 114.578° W.




**Figures 1-5.** *Navicula whitefishensis* from Upper Whitefish Lake, Flathead County, MT. Figure 1 is the holotype specimen. Scale bars = 10 µm

Sample collected from aquatic vegetation at a depth of 4 m by John Pierce on 18 August 1998.

### Paratype

Here designated as circled specimen on slide MDC 117-72 prepared from sample MDC 398301.

### Paratype locality

Redrock Lake, Glacier National Park, Montana, USA. 48.797° N, 113.706° W. Sample collected from rocks and sediment near shore by Loren Bahls on 28 June 2007.

### Ecology and distribution

This taxon is known only from the holotype and paratype localities, where it is uncommon and rare, respectively. Upper Whitefish Lake lies at an elevation of 1348 m above mean sea level. Specific conductance on the sampling date was 130 µS/cm and pH was 7.4. Redrock Lake lies at an elevation of 1540 m above mean sea level. Specific conductance on the sampling date was 94 µS/cm and pH was 7.1.

### Etymology:

This species is named for the holotype locality: Upper Whitefish Lake.

## Similar Species

*Navicula whitefishensis* is morphologically similar to *Navicula trivialis* (Figs. 6-11) and *Navicula oligotraphenta* (Figs. 12-18). Below I describe these two species based on populations from the Northern Rockies.

***Navicula trivialis* Lange-Bertalot 1980, p. 31, plate 1, figs. 5-9**

Valves are broadly lanceolate with apices acutely rounded and weakly protracted to somewhat rostrate. Valves are 25-65 µm long and 9.0-12.5 µm wide. The axial area is narrow, gradually widening toward a moderately large, rounded central area. The central area is 4.4-5.5 µm in diameter. The raphe is filiform to weakly lateral. Proximal raphe ends are relatively distant, expanded and weakly deflected to one side. Terminal raphe fissures are curved, opening toward the secondary side. Striae are radiate almost throughout, parallel then convergent only very near the poles, 11-13 in 10 µm. Areolae are rather indistinct and number 28-32 in 10 µm.

With 425 records, *Navicula trivialis* is one of the most common *Navicula* species in the Montana Diatom Collection. It is found in lakes and streams throughout the Northwest and in streams and rivers across the entire western United States (Rushforth & Spaulding 2010). In Northwest waters where this species is found, the mean pH is 7.7 and the mean specific conductance is 708 µS/cm. Lange-Bertalot (2001) reports that this cosmopolitan species prefers eutrophic waters with moderate levels of electrolytes.

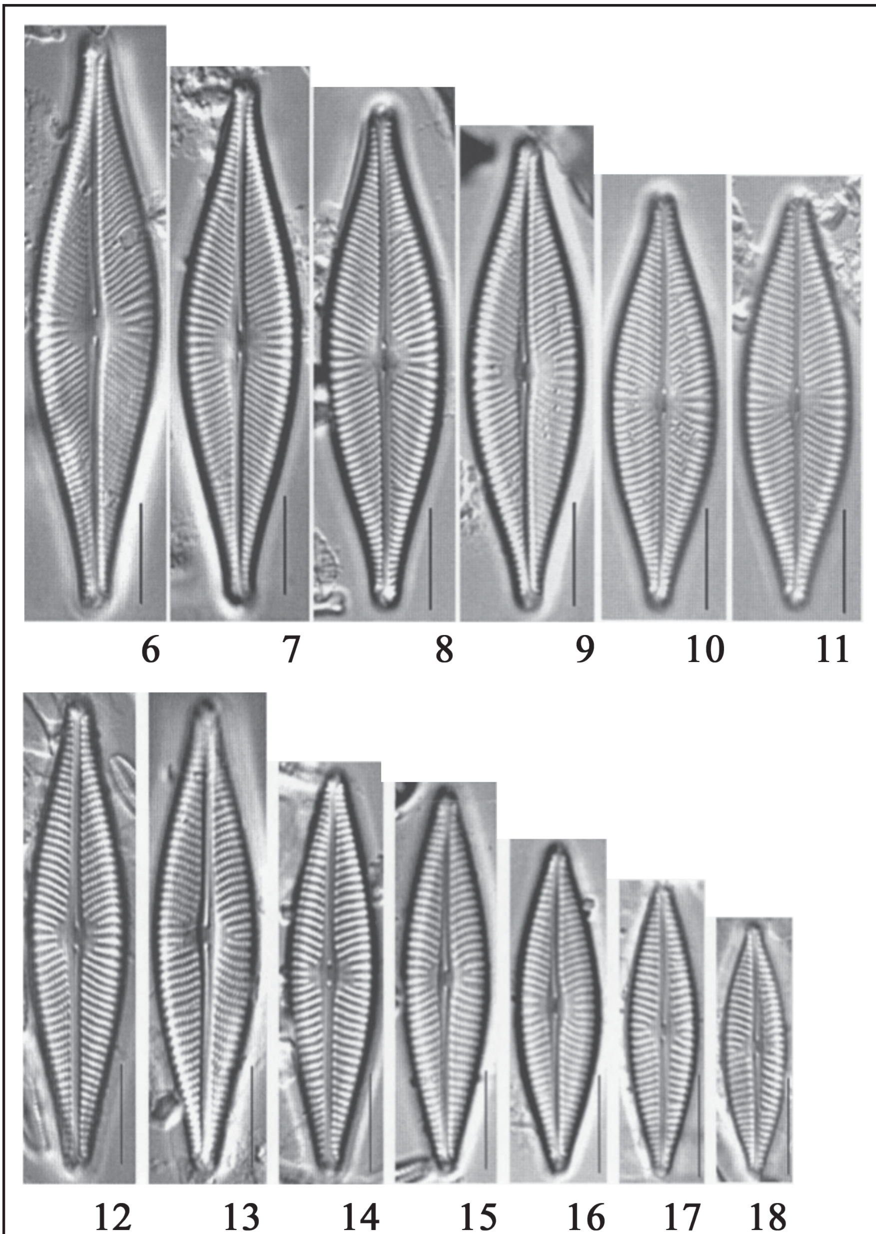
***Navicula oligotraphenta* Lange-Bertalot & Hofmann in Lange-Bertalot 1993, p. 128, plate 48, figs. 6-11; plate 49, figs. 3, 4**

Valves are lanceolate with weakly protracted and acutely rounded apices. Valves are 28-38 µm long and 8.0-9.5 µm wide. The axial area is narrow, gradually widening toward a small rounded central area. The central area is 2.5-4.2 µm in diameter. The raphe is filiform to weakly lateral. Proximal raphe ends are relatively close, expanded and weakly deflected to one side. Terminal raphe fissures are curved, opening toward the secondary side. Striae are radiate almost throughout, parallel then convergent only very near the poles, 10-12 in 10 µm. Areolae are rather indistinct and number 26-28 in 10 µm.

There are 92 records of *Navicula oligotraphenta* in the MDC, from lakes and streams in the Northwest. The mean pH of these waters is 8.2 and the mean specific conductance is 833 µS/cm. Lange-Bertalot (2001) reports this species as common in calciferous and oligotrophic to mesotrophic lakes in the Alps and their foothills.

## Comparison of species

The sample that produced the holotype slide of *Navicula whitefishensis* was not saved, hence it is not possible to examine specimens from type material under a scanning electron microscope (SEM). In the more recent



**Figures 6-18.** *Navicula trivialis* and *Navicula oligotraphenta* from the Northern Rockies. Figures 6-11. *Navicula trivialis* from Swiftcurrent Ridge Lake, Glacier National Park, MT (MDC sample 430301, MDC slide 118-76). Figures 12-18. *Navicula oligotraphenta* from Mission Creek, Benewah County, ID (MDC sample 340301, MDC slide 102-41). Scale bars = 10 µm.

paratype sample, for which cleaned material is available, *Navicula whitefishensis* is so rare (only one specimen was found) that SEM work was not practical. Nevertheless, the features that distinguish this taxon from similar taxa are quite apparent in LM.

Three features, easily observed in LM, distinguish *Navicula whitefishensis* from *Navicula trivialis* and *Navicula oligotraphenta*: (1) More abruptly protracted and narrower, subcapitate apices, even in the smallest specimens; (2) Wider valves (up to 14.2 µm); and (3) A larger central area. *Navicula whitefishensis* is further distinguished from *Navicula oligotraphenta* (but not from *Navicula trivialis*) by having more distantly spaced proximal raphe ends. In other respects—structure of the raphe, size and deflection of proximal raphe ends, orientation and spacing of the striae, and spacing of the areolae in the striae—the three taxa are quite similar.

Comparison of these taxa would benefit from SEM analysis of *N. whitefishensis*, if and when material containing sufficient numbers of this taxon becomes available.

## Acknowledgements

I thank John Pierce of Missoula, Montana for collecting the sample from which the holotype slide was made. Marina Potapova and an anonymous reviewer provided several helpful suggestions that improved the paper.

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# Rainbow Trout Spawning Characteristics and Relation to the Parasite *Myxobolus cerebralis* in the Missouri River, Montana

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## Abstract

The *myxosporean* parasite *Myxobolus cerebralis* is responsible for significant declines of rainbow trout (*Oncorhynchus mykiss*) populations in several western states, including Montana. Despite a high prevalence of the parasite in Montana's Missouri River, there have been no apparent impacts to the rainbow trout population. This study examined long-term *M. cerebralis* monitoring data from the Missouri River system below Holter Dam and evaluated rainbow trout spawning characteristics such as migration distance, spawning location, site fidelity and amount of spawning in the Missouri River and tributaries over three years in an attempt to explain why the population has not declined in the presence of *M. cerebralis*. Over 13 years of monitoring, a mean 5.3 percent of rainbow trout handled during population estimates had clinical signs of *M. cerebralis* infection. In experiments using sentinel fish 53 percent of the spawning habitat had high severity of *M. cerebralis*, 38 percent had low to moderate severity, and 9 percent had no infection. Radio telemetry showed spawning locations varied among years and tagged fish lacked spawning site fidelity. The distance that radio-tagged rainbow trout migrated to spawning locations was significantly different among river sections of the study area. Twenty-eight percent of the spawning redds were found in the Missouri River and 72 percent in the tributaries. Relative to previous studies, we found less tributary spawning and an increase in Missouri River spawning, where *M. cerebralis* infection severity is lower. Our findings suggest that diverse spawning behaviors may contribute to rainbow trout population stability by spreading the risk of *M. cerebralis* impact over spawning locations that have a broad range of infection severity.

**Key words:** rainbow trout, whirling disease, *Myxobolus cerebralis*, radio telemetry, redds, spawning

## Introduction

The Missouri River-Holter Dam tailwater fishery is one of the most productive trout fisheries in Montana. Out of 1,200 fisheries monitored for angler use statistics in Montana it consistently ranks as one of the top four most heavily fished waters (Montana Fish, Wildlife and Parks (MFWP) unpublished data). From 1995 through 2009 anglers spent an average 97,430 (range 75,000-123,000) days per year fishing this reach of river. The trout assemblage is approximately 83 percent rainbow trout (*Oncorhynchus mykiss*) and 17 percent brown trout (*Salmo trutta*). Brown trout and rainbow trout stocking began in 1928 and 1933, respectively, and continued intermittently though 1973. At that time, Montana instituted a statewide wild fish management policy and discontinued stocking trout in most rivers and streams. This trout fishery has been sustained by wild reproduction ever since. From 1980 through 2010 MFWP has conducted annual boat-mounted electrofishing mark-recapture population estimates of trout greater than 25 cm long in two sections of this river.

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Median estimates for number of trout 25 cm and longer per km in the 8.9 km-long Craig section are 1,793 (range =1,096-3,185) for rainbow trout and 306 (range =91-827) for brown trout (Fig. 1: Grisak et al. 2010). In the 6.6 km-long Pelican Point section median estimates are 885 (range =389-2,360) for rainbow trout and 193 (range =84-427) for brown trout (Fig. 1: Grisak et al. 2010).

In 1995, *Myxobolus cerebralis*, a myxosporean parasite that causes whirling disease in rainbow trout, was discovered in Little Prickly Pear Creek; one of the most productive trout spawning tributaries of the Missouri River below Holter Dam (Leathe et al. 2002, Munro 2004). Within three years, clinical signs of whirling disease, such as black tail and whirling behavior, were observed in wild age-0 rainbow trout in Little Prickly Pear Creek (Grisak 1999). The parasite's range expanded into the Missouri River and some additional spawning tributaries over the next four years (Grisak 1999, Leathe 2001). This development raised great concern among fishery managers because from 1991 to 1994 the Madison River, Montana and the Colorado River, Colorado experienced sharp declines of rainbow trout, approaching 90 percent, due to *M. cerebralis* (Vincent 1996, Nehring and Walker 1996). Fearing similar population declines in the Missouri River, fishery managers investigated the relative recruitment of rainbow trout from tributaries where the parasite was established to total rainbow trout production (Leathe 2001, Munro 2004). Monitoring *M. cerebralis* in the Missouri River and its tributaries began in 1997 to evaluate the spread of the parasite and to develop population risk assessments. This monitoring has continued for 13 years.

Historically, fishery managers hypothesized that rainbow trout life history in this area was locally adapted, believing that fish in the upstream portion of this section spawned in Little Prickly Pear Creek, and fish in the downstream portion spawned in the Dearborn River (Horton et al. 2003, Horton and Tews 2005, Horton and Hamlin 2006). The presence of *M. cerebralis* in both of these spawning tributaries fueled speculation that the adult populations would ultimately become recruitment limited, resulting in population declines (McMahon et al. 2001, Leathe et al. 2002, Munro 2004). Despite 15 years of *M. cerebralis* presence in the most productive spawning tributaries, there has been no measurable reduction of adult rainbow trout in the Missouri River (Grisak 2010). We hypothesized that rainbow trout spawning behavior may be responsible for the stable populations.

In this study we (1) describe annual timing of spawning migrations and locations to test the hypothesis of localized spawning behavior, (2) estimate the amount of spawning that occurs in the Missouri River compared to its tributaries, (3) describe spawning migration behavior over multiple years, (4) describe the magnitude of spawning migrations over multiple years, (5) estimate the scale at which repeat spawners return to previous spawning sites as a measure of spawning site fidelity, and (6) summarize the *M. cerebralis* monitoring data collected over the past 13 years.

## Study area

The study area was located in central Montana and consisted of a 41.6-km reach of the Missouri River and its tributaries extending from Holter Dam downstream to the Pelican Point Fishing Access Site (Fig. 1). At the lower end of the study area, the Missouri River drains 47, 187 km$^2$ and had a gradient of 0.88m/km. Three upstream hydroelectric dams (Canyon Ferry, Hauser and Holter) regulate flows. Mean annual discharge measured below Holter Dam from 1946 to 2010 ranged from 85 to 241 m$^3$/s (USGS unpublished data for station 06066500) and mean annual water temperature was 8.4$^o$C (SE: 0.17). The principal spawning tributaries in the study area were Little Prickly Pear Creek (which included Lyons Creek and Wolf Creek), the Dearborn River, and Sheep Creek (Fig. 1). Little Prickly Pear Creek originates near the Continental Divide and flows easterly from the Rocky Mountains for 57 km before entering the Missouri River 3.8 km downstream of Holter Dam. Little Prickly Pear Creek basin drains 1,026 km$^2$. Mean

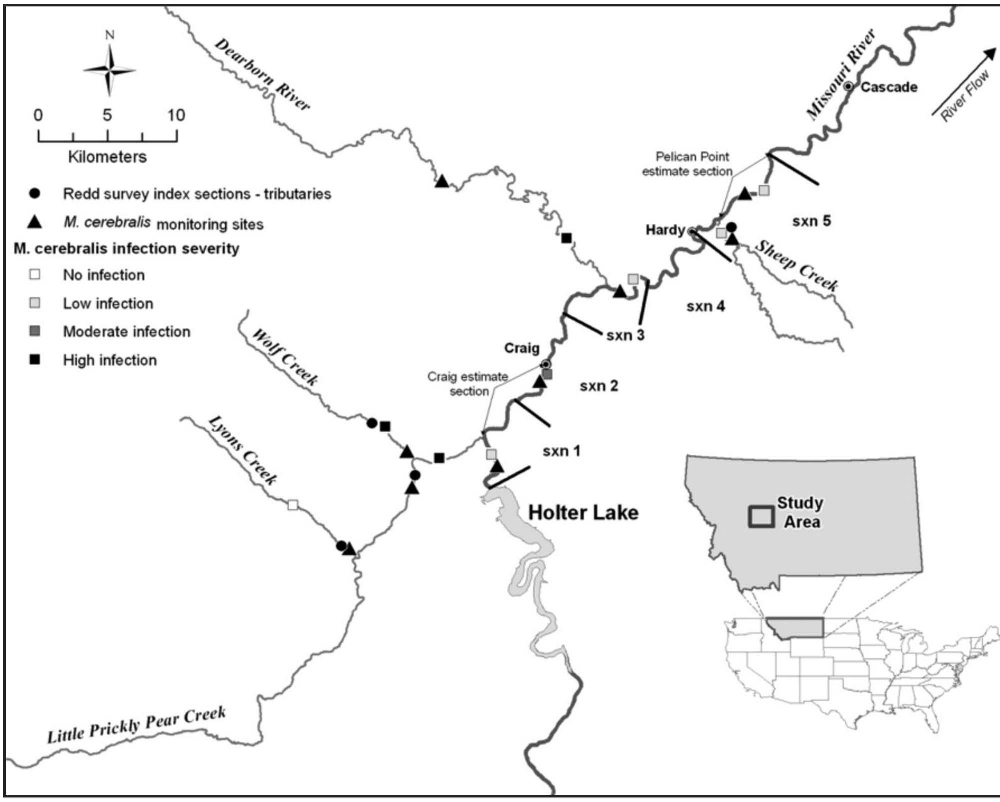


**Figure 1.** Missouri River-Holter Dam tail-water study area with population estimate sections, *M. cerebralis* monitoring sites, and *M. cerebralis* infection severity.

annual discharge from 1963 to 2010 ranged from 1.25 to 5.06 $m^3/s$ (USGS unpublished data for station 6071300) and mean annual water temperature was 7.7$^oC$ (SE: 1.03). The Dearborn River originates on the east slope of the Rocky Mountain front, near the Continental Divide, and flows easterly for 107 km before entering the Missouri River 25.3 km downstream of Holter Dam. This basin drains 1,418 $km^2$ and the mean annual discharge from 1946 to 2010 ranged from 1.7 to 10.3 $m^3/s$ (USGS unpublished data for station 6073500). Mean annual water temperature was 7.7$^oC$ (SE: 0.18). The North and South forks of Sheep Creek originate in the Big Belt Mountains and each flows for approximately 10 km before forming Sheep Creek. Sheep Creek flows westerly for 3.3 km before entering the Missouri River 37.8 km downstream of Holter Dam. The Sheep Creek basin drains 96 $km^2$. Temperature data were not available for Sheep Creek.

# Methods

## Radio Telemetry

We used radio telemetry to describe rainbow trout spawning migrations from 2008 through 2010 and estimate spawning site fidelity among years. We divided the Missouri River portion of the study area into five sections (each 8.3-km long) and dedicated an equal number of transmitters for each section. We tested two hypotheses relating to the scale at which trout migrate to spawn. The first hypothesis, derived from previous managers, was whether fish from the upper half (sections 1 and 2) of the study area would preferentially spawn in Little Prickly Pear Creek and fish from the lower half (sections 3, 4 and 5) would spawn in the Dearborn River. The second hypothesis we tested was whether all fish would spawn within the 8.3 km-long section of the Missouri River in which they were tagged.

Three of the sections (1,3,5) had tributaries that were considered part of the section.

Fish were captured using boat electrofishing (smooth DC, 300 V, 4 A). We selected individual rainbow trout ranging from 40 to 60 cm total length (TL) to ensure fish were sexually mature, young enough to spawn in the next two seasons, and large enough to carry the radio transmitter (<6.7 % total body weight) without influencing behavior (Brown et al. 1999). We surgically implanted radio transmitters (Lotek MCFT-3A, 148 MHz, 6.7g in-water weight) in the abdomen of six trout in each section following the external antennae procedure described by Cooke and Bunt (2001). Fish were tagged approximately six months before the spawning season to allow them to acclimate to transmitters. Because of predation by osprey (*Pandion haliaetus*), bald eagle (*Heliaeetus leucocephalus*), and great blue heron (*Ardea herodias*) and angler transmitter returns, four radios were recovered and re-implanted in new fish. We tagged 23 female and 7 male rainbow trout (range 42.4-51.1 cm TL). In the upper half of the study area we tagged 14 female and 4 male fish and in the lower half we tagged 9 female and 3 male fish. Mean body weight loading of the transmitters was 1.65 percent (SE: 0.08).

Tagged fish were detected using a mobile radio-telemetry receiver (Lotek SRX 400 W5) and a truck, jet boat, or airplane. Stationary radio receivers (Lotek SRX 400 W7AS) were positioned at the mouths of Sheep Creek, Dearborn River and Little Prickly Pear Creek, and at the Craig Bridge (Fig. 1). Receivers at tributary mouths provided precise dates and times when fish entered or exited the tributaries.

Mobile surveillance was increased during spawning seasons in order to locate spawning sites. We had a priori knowledge from previous spawning studies in this area that radio-tagged rainbow trout ascended tributaries and stayed at redd sites for a mean 4.7 days (range 1-22) before moving downstream (Grisak 1999). Given the difficulty in determining exact spawning sites, we estimated spawning locations and times by documenting a fish's furthest movement during the spawning season and assuming it spawned in the area at that time (Grisak 1999, Burrell et al. 2000, Henderson et al. 2000, Pierce et al. 2009).

Locations of tagged fish were recorded on a map with longitudinal distances of the Missouri River and its tributaries marked to the nearest 0.1 km. The beginning reference point (river kilometer [rkm] 0.0) in the Missouri River was Holter Dam, located on the upstream end of the study area (Fig. 1). For tributaries, the beginning reference point (rkm 0.0) was the mouth of each stream and longitudinal measurements continued upstream.

## Redd Counts

We counted spawning redds in the tributaries and the mainstem Missouri River from 2007 to 2010 to estimate the spatial distribution and relative magnitude of rainbow trout spawning each year. Redd counts were conducted weekly by surveying index sections of tributary streams starting on 15 March (Fig 1). The peak of the spawning run for each stream was calculated using the mean value of all redds counted in the index sections and determining the dates of the peak. At the point when few additional redds and few or no spawning fish were observed in the index sections, we conducted an expanded basin-wide count in each stream within one week (Grisak 1999). Redd counts on the Missouri and Dearborn rivers were conducted using a Bell OH-58 helicopter with the doors removed flying ≈75 meters above the water's surface. Two observers wearing polarizing eyeglasses counted redds and recorded the locations with a GPS unit. The spatial distribution of redds in the rivers was determined using ArcGIS. Two-way communication between the observers reduced the likelihood double-counting redds in the center of the rivers.

## *M. cerebralis* monitoring

Monitoring of *M. cerebralis* was conducted according to protocols described by Baldwin et al. (2000) and Vincent (2002). Caged sentinel fish (60 age-0 rainbow trout) were placed in streams for 10-d periods when water temperatures were conducive to promote infections in rainbow trout (9-17$^{o}$C: Vincent 1999). An Onset temperature data recorder attached to the cage recorded water temperatures on 30 minute intervals during the exposure period. In order to measure the peak and range of infection severity at many of the sites, multiple 10d sequential sentinel fish experiments were conducted when mean daily water temperature ranged from 9 to 17$^{o}$C. After exposure, the fish were moved to a laboratory facility where the parasite was allowed to mature in infected fish over a 90-d period. The fish were euthanized with tricane methanesulfonate (MS-222) and prepared for histological analyses by first removing and then preserving the head and gill arches in formalin. Histological analyses were performed on median plane sections of fish heads, which involved quantifying the abundance and severity of *M. cerebralis* lesions in cranial tissue.

The severity of infection was rated on a 0-5 scale for each fish and histological scores were averaged for each lot (Hedrick et al. 1999, Baldwin et al. 2000, Vincent 2002). Population risk assessments were developed based on reports that mean histological score of 2.75 and higher usually cause declines in wild rainbow trout populations (Vincent 2002). From this we developed three risk categories based on mean histology score (>2.75 = high, < 2.74 = moderate, 0.00 = no risk).

We also measured clinical signs of whirling disease such as deformed mandible/maxilla, shortened operculum, dolphin head and spinal deformity (Vincent 2002) while handling fish during annual rainbow trout population estimates.

### Data Analysis

Because we evaluated fish movements over multiple years, it was necessary to define a starting point for fish movements each year. For the first year, the starting point was the 8.3 km-long section of the Missouri River where each fish was collected and implanted with a radio transmitter. For each successive year the starting point was the section where each fish was located on 1 January. We used chi-square goodness-of-fit tests ($\alpha<0.05$) to determine whether the predicted number of fish that spawned within their annual starting section or the upper and lower half of the study area was significantly different from that observed.

We hypothesized that the distance rainbow trout moved to spawning sites would be similar among the five groups. Migration distances from annual starting sections to spawning locations were evaluated using single factor analysis of variance (ANOVA: $\alpha<0.05$) to determine whether magnitudes of movements were significantly different among sections.

Histopathology and water temperature data were analyzed using logistic regression (Peng et al. 2002). Mean histology scores and mean daily water temperature were the ranked categories. Histology scores were ranked according to risk of population impacts (>2.75 = high, <2.74 = low). A maximum likelihood estimate was used to determine if there was a significant ($\alpha<0.05$) relationship between water temperature and risk category and an odds ratio estimate was used to determine the odds of sentinel fish test lots being in one of the risk categories and what influence temperature had on the odds ratio. Tests were performed using the proc logistic procedure in SAS.

## Results

### Radio Telemetry

We relocated the 30 radio-tagged rainbow trout a total of 1,577 times and mean relocations per fish was 34 (range 1-134).

Rainbow trout spawning was not localized to the half of the study area in which they were tagged ($\chi^2$=9.76, df=1, $P$=0.009). We found no significant difference between the number of fish that spawned within or outside of the five sections ($\chi^2$=0.08, df=1, $P$=0.39). The distance that rainbow trout migrated to spawning locations was significantly different among the five sections (ANOVA:

$F$=3.44; df=3,20; $P$=0.03). Fish from the uppermost section (Section 1) of the Missouri River moved the greatest mean distance (28.9 km, SE: 9.0) to spawning locations. Fish from each section entered the Dearborn River to spawn, yet 36 percent of the Dearborn spawners migrated downstream from section 1.

In 2008, 88 percent of the radio tagged rainbow trout made spawning migrations and 62 percent of these moved outside of their starting section to spawn. Of the tagged fish that made spawning migrations, 73 percent spawned in the Missouri River and 27 percent spawned in the Dearborn River. Tagged fish migrated a mean 17.0 (SE: 4.0) km to reach spawning sites (Table 1).

In 2009, 81 percent of the radio-tagged rainbow trout migrated to spawning sites and only 20 percent of these moved outside of their starting section to spawn. The mean distance fish traveled to reach spawning sites was 13.1 (SE: 6.3) km (Table 1). Only one fish from each section traveled outside of their respective section to spawn in 2009. Fish from sections 2 and 4 moved the greatest distance to spawning sites (81.6 km and 59.6 km, respectively).

In 2010 only half of the radio tags were transmitting and only 20 percent of the fish with active tags moved outside of their home section to spawn. The mean distance fish traveled to reach spawning sites was 20.8 (SE: 13.9) km (Table 1), but this mean estimate is heavily influenced by one fish that left the study area in late 2009 and resided near the town of Great Falls over the winter. In early 2010, it traveled 116.8 km from its starting section to spawn in the Dearborn River for the second time in three years. Excluding this fish, the remaining fish traveled a mean distance of 7.1 (SE: 2.7) km to spawning sites.

Overall, radio-tagged rainbow trout were presumed to have spawned, based on their movements, over a 79 d period from 3 March to 5 May. Over the three-year period, 69 percent of rainbow trout spawned only in the Missouri River, 31 percent spawned in a tributary at least one time, 12 percent spawned in tributaries multiple times, 73 percent spawned in consecutive years, 27 percent spawned only once and, 15 percent spawned in a different river or stream. Tagged fish traveled a mean 16.4 (SE: 3.7) km to reach spawning sites (Fig 2).

After spawning, 21 percent of the rainbow trout returned to within 1.6 km of their starting point for that year, but the remaining fish moved to new locations after spawning. Only 8 percent of the rainbow trout displayed repeat tributary spawning in two successive years. The mean distance between spawning locations for repeat tributary spawners was 6.5 (SE: 0.2) km. Missouri River mainstem spawners accounted for over half (58%) of the sample. Mean distance between spawning locations for repeat mainstem spawners was 6.1 (SE: 2.1) km. The average total distance rainbow trout traveled over the three year period was 68.5 km (SE: 17.4). Only 11 percent traveled more than 160 km in any one calendar year. Radio- tagged rainbow trout spawned in each of the five sections in the Missouri River and in the lower 52.8 km of Dearborn River (Fig 2.). None of the radio tagged fish entered the Little Prickly Pear drainage (Little Prickly Pear Creek, Lyons Creek, Wolf Creek) or Sheep Creek during the study. Over half (52%) of rainbow trout traveled downstream to reach spawning locations.

**Table 1.** Spawning migration characteristics of radio-tagged rainbow trout in the Missouri River, Montana, 2008-10.

| Year | % of tagged fish that spawned | Mean km traveled to spawn | Standard error (km) | Range (km) |
|---|---|---|---|---|
| 2008 | 88 | 17.0 | 4.0 | 0.1-64.4 |
| 2009 | 81 | 13.1 | 6.3 | 0.1-81.6 |
| 2010 | 20 | 20.8 | 13.9 | 0.3-116.8 |
| All years | --- | 16.4 | 3.7 | --- |

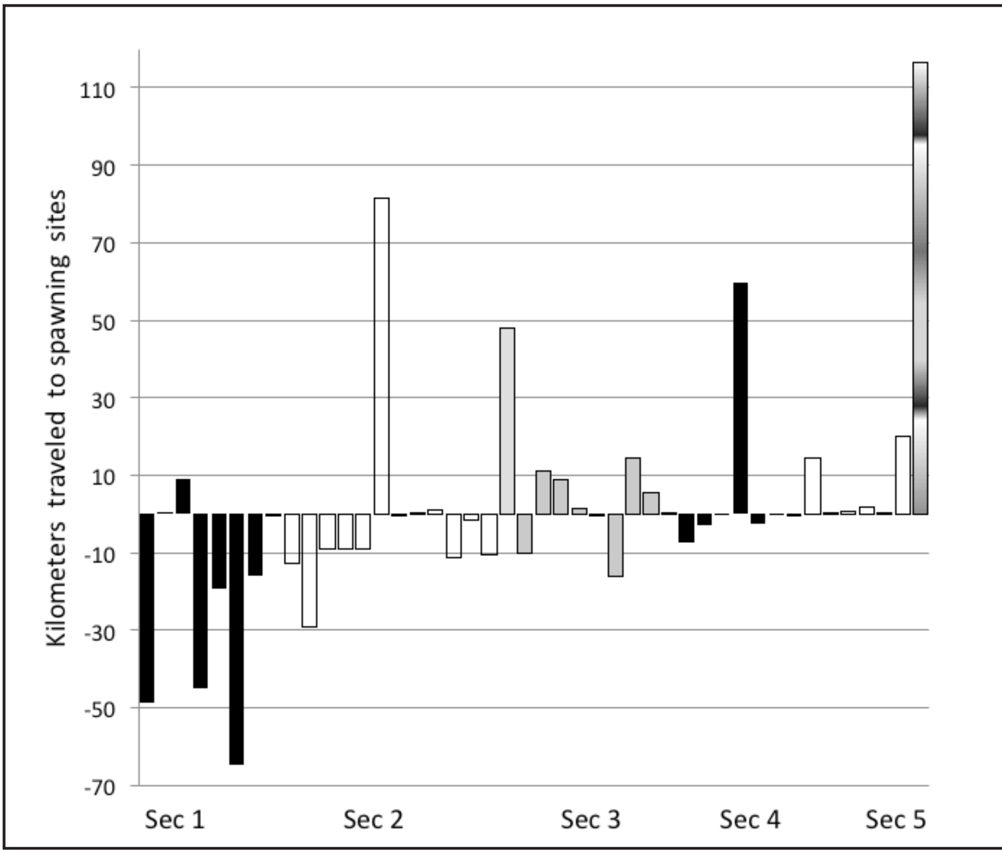


**Figure 2.** Distance radio-tagged rainbow trout traveled to spawning sites upstream (+km) and downstream (-km) by section, Missouri River, Montana 2008-2010. Gradient filled bar represents a fish that left the study area and then returned to spawn.

## Redd Counts

In April 2007, the Missouri River portion of the study area was surveyed to identify the spatial distribution of redds. The mean distance between redds in the Missouri River was 1.89 (SE: 0.21) km. Spawning redds were distributed throughout the entire longitudinal reach of the Missouri River.

During the Spring of 2010 weather conditions (wind, overcast, rain) and flow (122 m3/s) in the Missouri River were favorable for observing redds from the air and 39 percent (1,644) of the redds we counted occurred in the Missouri River (Table 2). We observed redds in deep water (> 2 m deep) at six locations in the Missouri River. The greatest number of deep water redds was 47 which occurred at rkm 3.5, followed by 24 redds at rkm 4.9, 11 redds at rkm 14.2, 2 redds at rkm 16.9, 2 redds at rkm 18.4 and 6 redds at rkm 22.7. From 2008-10 the spatial distribution of redds spanned 122 km of river and stream annually. Overall, 28 percent of the mean number of annual redds occurred in the Missouri River and 72 percent occurred in tributaries (Table 2). The mean annual number of redds for the entire system was 4,071 (SE: 378) (Table 2). Little Prickly Pear Creek had 44-47 percent of the total annual redds, the highest mean number of redds and the highest mean density (92/km) of redds. The Dearborn River had the lowest mean density at 21/km (Table 2).

## *M. cerebralis* monitoring

Little Prickly Pear Creek had the highest *M. cerebralis* infection scores in 11 of 13 years (Table 3). Other streams

**Table 2.** Rainbow trout redds counted during the basin wide surveys and redd density (redds/km) for the Missouri River and tributaries, Montana 2007-10.

| Stream | Dist (Km) | Number of redds (redds per km) 2007 | 2008 | 2009 | 2010 | Mean | Rel % |
|---|---|---|---|---|---|---|---|
| Missouri River | 41.6 | --- | b | b | 1644 (40) | 1644 (40) | 28 |
| Dearborn River | 30.4 | --- | b | b | 632 (21) | 632 (21) | 10 |
| Little Prickly Pear Cr. | 19.5 | 2125 (109) | 1461 (75) | b | b | 1793 (92) | 29 |
| Lyons Creek | 11.2 | 847 (76) | 897 (80) | b | 386 (34) | 710 (63) | 11 |
| Wolf Creek | 12.5 | 1289 (103) | 678 (54) | b | 1451 (116) | 1139 (91) | 18 |
| Sheep Creek | 3.2 | 282 (88) | 286 (89) | b | 234 (73) | 267 (83) | 4 |
| **Total** | | **4543** | **3322** | | **4347** | **4071** | |

b - high turbid flows precluded counting redds

with multiple high (> 2.75) scores over the monitoring period were Wolf Creek (58%) and the Dearborn River (50%). In the Missouri River, the Craig monitoring site had high scores in 6 of 13 (46%) years and was the only Missouri River site with multiple scores greater than 2.75. Overall, 53 percent of the habitat used by rainbow trout for spawning had a high severity of *M. cerebralis*, 38 percent had low to moderate severity, and 9 percent had no infection, as detectable by sentinel fish. Lyons Creek remains the only stream in our study area where the parasite has not been detected.

From 1997 to 2009, 5.3 percent (range 1.7-8.9%) of the rainbow trout sampled during the annual population estimates displayed clinical signs of *M. cerebralis* infection (jaw deformity, shortened operculum, dolphin head and spinal deformity: Table 4). Dolphin head was the deformity that occurred the most. The highest numbers of deformed fish occurred in 2001, when 8.9 percent of the fish handled during the population estimate displayed clinical signs of *M. cerebralis* infection.

*Myxobolus cerebralis* infection in sentinel fish occurred from 6 May to 3 July (median = 31 May). The dates of exposure for test lots with mean infection scores of 2.75 and greater ranged from 15 May to 3 July (median = 30 May) and the dates of exposure for tests lots with mean infection scores of 2.74 and less ranged from 5 May to 3 July (median = 1 July).

There was a significant relationship between histopathology rank and temperature (maximum likelihood estimate, $P=0.02$). The mean daily water temperature in test lots with infection scores 2.75 and greater was 11.6°C (range = 8.7-16.5), whereas it was 12.9°C (range = 9.6-18.1) for test lots with scores 2.74 and less. The odds of sentinel fish test lots being classified as low risk was higher by 1.097 for each degree temperature increase and the odds increased by a factor of 2.519 for every 10 degree increase in temperature.

## Discussion and Conclusions

A variety of factors may influence the relative impact that *M. cerebralis* has on rainbow trout populations. Among these are life history and spawning behaviors (Downing et al. 2001, Pierce et al. 2009), differential infection susceptibility among strains of fish (Vincent 2002), habitat conditions (Granath et al. 2007) and water temperature at time of emergence and during early-life rearing (Baldwin et al. 2000).

Where native, rainbow trout have demonstrated discrete spawning behaviors and site fidelity for spawning, feeding and overwintering (Meka et al. 2003). The data from this study did not support the hypotheses that radio-tagged fish would spawn within their annual starting section or that spawning was localized to either half of the study area. The location of rainbow

**Table 3.** Mean cranial lesion histopathology scores (0-5) from sentinel rainbow trout exposed to *M. cerebralis* at select sites in the Missouri River below Holter Dam and its tributaries. Values represent the highest mean infection severity measured for any 10 d period for each year.

| Stream -site | Year | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
| Little Prickly Pear Creek - Wirth div | 2.94 | 3.98 | 4.66 | 4.76 | 4.43 | 4.96 | 4.92 | 4.87 | 4.97 | 0.11 | 4.72 | 1.96 | 4.70 |
| Lyons Creek - mouth | --- | 0.00 | --- | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | --- | 0.00 | --- |
| Wolf Creek - mouth | --- | 1.24 | 0.20 | 0.78 | 4.47 | 3.96 | 3.98 | 4.80 | 4.42 | 0.15 | 4.58 | 2.70 | 3.94 |
| Missouri River - Holter Dam | 0.00 | 0.00 | 0.28 | 0.14 | 0.16 | 0.20 | 0.00 | --- | --- | --- | --- | 0.00 | 0.00 |
| Missouri River - Craig | 0.66 | 1.83 | 3.88 | 2.82 | 3.47 | 2.22 | 1.76 | 3.33 | 3.78 | 0.15 | 2.02 | 4.02 | 0.85 |
| Missouri River - Mid Canon | --- | 0.00 | --- | 0.30 | 1.60 | 0.19 | 0.34 | 2.00 | 3.00 | 0.13 | 1.96 | --- | 1.44 |
| Missouri River - Pelican Point | --- | 0.02 | 2.35 | --- | 0.26 | 0.10 | 0.12 | 0.97 | 1.66 | 0.00 | 1.80 | 0.04 | 1.56 |
| Dearborn River - Hwy 287 | --- | 0.00 | 0.00 | 0.00 | 0.07 | 1.18 | 2.58 | 4.59 | 4.72 | 4.13 | 3.00 | 4.27 | 4.13 |
| Sheep Creek - mouth | 0.00 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | --- | 0.08 | 0.00 | --- | 0.34 | --- |

trout at the point of tagging or on 1 January was not an indicator of where they spawned. The mean distance and maximum distance that fish traveled to spawning locations was greater than has been reported for other rainbow trout populations (Adams 1996, Lisac 1996, Meka et al. 2003). In many instances fish traveled over suitable habitat, as evidenced by existing redds, to reach eventual spawning destinations. Such behavior suggests a determination to reach a specific area for spawning, but the majority of fish lacked spawning site fidelity between years.

Low site fidelity may be an important life history characteristic that spreads the risk posed by *M. cerebralis* over spawning locations with a broad range of infection severity. There is some speculation of differing virulence of *M. cerebralis* strains based on geographical location (Modin 1998). Other studies in our area showed a high degree of spatial variation and *M. cerebrali*s infection intensity in the primary host *Tubifex tubifex* (McMahon et al. 2001). The variable infection severity in *T. tubifex* may contribute to the variable levels of disease severity seen among stream salmonid populations (Stevens et al. 2001). Relating this to infection in fish or fish population declines has proven difficult in other areas. For example, despite variable *M. cerebralis* infection in *T. tubifex* among varied habitats in the Rock Creek drainage of Montana, lower infections in this host did not necessarily translate to lower infections in fish because the infectious stage of the parasite (triactinomyxon) spreads rapidly in flowing water (Granath et al. 2007).

The low spawning site fidelity observed in our study and the broad spatial scale over which fish redistributed after spawning were in contrast to other research but are behaviors that could facilitate avoidance of unfavorable habitat conditions (Adams, 1996, Adams 1999, Meeka et al. 2003, Pierce et al. 2009). Whether the difference represent behavioral changes in response to *M. cerebralis*, or differences in behavior have been longstanding components of the trout life history, remains unknown.

**Table 4.** Relative occurrence of clinical signs of *M. Cerebralis* infection in wild rainbow trout sampled during population estimates in the Craig section of the Missouri River, Montana 1997-2009.

| Year | BB | SOP | DH | JAW | Total deformed | Total rainbow trout handled | % of deformed in total catch |
|---|---|---|---|---|---|---|---|
| 1997 | 45 | 19 | 18 | 10 | 92 | 5339 | 1.72% |
| 1998 | 23 | 15 | 107 | 8 | 153 | 5329 | 2.87% |
| 1999 | 54 | 20 | 116 | 40 | 230 | 5036 | 4.57% |
| 2000 | 87 | 19 | 111 | 60 | 277 | 4835 | 5.73% |
| 2001 | 176 | 16 | 158 | 46 | 396 | 4475 | 8.85% |
| 2002 | 121 | 15 | 143 | 58 | 337 | 4735 | 7.12% |
| 2003 | 68 | 33 | 84 | 74 | 259 | 4272 | 6.06% |
| 2004 | 67 | 19 | 97 | 40 | 223 | 3885 | 5.74% |
| 2005 | 58 | 47 | 80 | 57 | 242 | 4163 | 5.81% |
| 2006 | 34 | 24 | 71 | 48 | 177 | 3269 | 5.41% |
| 2007 | 19 | 37 | 52 | 44 | 152 | 4117 | 3.69% |
| 2008 | 20 | 35 | 55 | 53 | 163 | 2636 | 6.18% |
| 2009 | 14 | 24 | 55 | 73 | 166 | 3742 | 4.44% |

BB – bent back/spinal deformity
SOP – shortened operculum
DH – dolphin head
JAW – deformed mandible/maxilla

After spawning, the majority (79%) of tagged fish moved to sites other than their pre-spawn locations. In other areas where *M. cerebralis* has caused reductions in rainbow trout populations, 75 to 76 percent of spawners returned to within 1.5 to 2.0 km of their pre spawn location (Downing et al. 20032, Pierce et al. 2009). The fact that some fish spawned only once during the study suggests the possibility of alternate year spawning by a low percentage (27%) of rainbow trout in the Missouri River system. Alternate year spawning has been reported in female rainbow trout in tributaries to the King Salmon River in Alaska (Adams 1999) and is typical of fish with slow metabolism that cannot store the proper amount of energy necessary to develop eggs and make migrations to spawning areas (Palstra et al. 2010).

Comparing these results with the limited historic rainbow trout life history information for this area suggest a higher use of the Missouri River for spawning (Munro 2004, Leathe et al. 1988, McMahon et al. 2001). Changes in the number of redds included a 27 to 37 percent decrease in the tributary streams (Little Prickly Pear, Lyons, Wolf creeks: Grisak 1999), 77 percent decrease in the Dearborn River and 64 percent increase in the Missouri River (Leathe et al. 1988). Such changes may contribute to the persistence of rainbow trout in the Missouri River-Holter Dam tailwater fishery because *M. cerebralis* infections measured in the Missouri River are less severe than in its tributaries. By comparison, spawning by rainbow trout in Montana's Madison River system occurs mostly in the mainstem and is concentrated in the upper reaches where the majority of emerging young are susceptible to a high prevalence of *M. cerebralis* (Downing et al. 2002). Other research has shown that life histories of rainbow trout could lead to higher *M. cerebralis* infection if young fish have to migrate through areas with a high density of infected *T. tubifex* (Sandell et al. 2001).

Over the 13-year monitoring period the adult rainbow trout population in the Missouri River remains near the long term median despite high (>2.75 histopathology score) *M. cerebralis* severity measured in sentinel fish in over half (53%) of the available spawning habitat (Table 2: Grisak et al. 2010). Three of the four Missouri River monitoring sites (Holter, Mid Canon, Pelican Point) had relatively low infection severities compared to the Craig site. The high infection severity at the Craig site may be related more to its proximity to Little Prickly Pear Creek, located 7.4 rkm upstream, than to the infection severity in the Missouri River. Granath et al. (2007) reported that infections in sentinel fish may be the result of triactinomyxons produced hundreds or thousands of meters upstream. In essence, localized heavily degraded habitats, suitable to infected *T. tubifex*, may serve as a major source of infection at a broader scale than would be assumed from sampling the distribution of *T. tubifex* worms or from the results of sentinel fish studies. The monitoring site that had the second highest infection severity scores was the Mid Canon site, which is located 2.4 rkm downstream of the Dearborn River.

Histopathology rank was correlated to water temperature. Mean water temperature at sites with high severity infections was slightly less than at sites with low to moderate severity infections suggesting infection severity peaks as water temperature rises and then drops as water temperature increases above 12°C. Other field experiments with rainbow trout showed the highest infection intensities occurred when water temperatures were between 12 and 16°C then declined rapidly as mean daily water temperatures decreased or increased from these optimum water temperatures (Vincent 2002).

There is evidence of differing infection susceptibility among rainbow trout strains (Vincent 2002). However, attributing the stability of rainbow trout populations in the Missouri River to a particular strain would be difficult because rainbow trout are not native to this region and the population was founded by over 40 years of stocking undesignated strains. Since 1973, the population has been influenced by at least 12 strains of rainbow trout (Eagle Lake, Arlee, Erwin, DeSmet, Madison River, Shasta, McConaughy, Bozeman, Lewistown, Winthrop, Beula, Wild) stocked in the upstream reservoirs (Holter, Hauser, Canyon Ferry: MFWP unpublished data). Given the unknown origin of the majority of rainbow trout stocked in this area, as well as the uncertain contribution from 12 different strains there is no way of knowing which strains have succeeded or persisted over time. The consequences of such a stocking history may be a population that has a high level of gene flow and lacks selective pressures for distinct behavior patterns and spawning site fidelity (Allendorf and Phelps 1981, Slatkin 1985, Slatkin 1987), as our results show. These concepts have been studied extensively in Pacific salmon species when evaluating the interaction of wild and hatchery-reared fish and potential changes in local genetic adaptations (Hendry et al. 1996, Quinn 1993, Quinn et al. 2006).

The 79-d rainbow trout spawning period observed in our study indicates the fry emergence period would be broad enough to span the entire thermal range of *M. cerebralis* infection susceptibility. As such, fish of each cohort could be either unaffected or exposed to the parasite at levels which they likely survive. With such a broad spawning period, fry from early and late spawning fish could emerge at times when water temperatures are outside of the range of *M. cerebralis* infection (Vincent 2002), or when high spring flows dilute the concentration of triactinomyxons and flush fry out of tributaries into the Missouri River where the infection severity is less. The timing of outmigration of young rainbow trout can influence *M. cerebralis* infection. Infection can occur for a minimum of 60 to 65 days post hatch (Baldwin et al. 2000, Vincent 2002, Downing et al. 2002). Fish that migrate out of natal streams at age-0 have been shown to have a higher infection severity than fish that migrated at age-1 (Leathe et al. 2002).

This study found that the only observable impact of *M. cerebralis* infection to the adult population was the small number (<9%) of adult rainbow trout that we encountered during population estimates that had clinical signs of *M. cerebralis* infection. Despite no outbreak of whirling disease, a small segment of the rainbow trout population persists with a mild infection. The spawning behaviors we have described likely contribute to the stability of the rainbow trout populations in the Missouri River, even after 15 years of *M. cerebralis* presence in the study area.

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# Mycobacteriosis in a Bull Trout From Hungry Horse Reservoir, Montana

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## Abstract

An angler-caught bull trout (*Salvelinus confluentus*) from Hungry Horse Reservoir, MT with noticeably poor condition was examined to reveal liver nodules. Further investigation discovered acid-fast bacteria present in these granulomas making this a unique finding requiring further diagnostics. Molecular diagnostics revealed the infectious agent to be *Mycobacterium fortuitum*. This is a range and species expansion for this pathogen in fish. Further examination of additional fish from this water body did not reveal cases similar to this one, allowing for the possibility of this being a lone occurrence.

**Key Words:** Mycobacteriosis, *Mycobacterium,* bull trout, fish

## Introduction

Mycobacteriosis is a common disease affecting cultured and wild fishes worldwide (Gauthier & Rhodes, 2009). Infected fish exhibit clinical signs including loss of scales, depigmentation, hyperpigmentation, cachexia, abnormal behavior and lethargy (Lansdell *et al.*, 1993). Postmortem examination often reveals gray to white nodules in many organs (Heckert *et al.*, 2001) due to this infection. In fish, kidney, liver and spleen tissue are commonly found with nodules or granulomas present in infected individuals (Heckert *et al.*, 2001). Historically three species have been recognized to be pathogenic to fish; *M. chelonae, M. fortuitum,* and *M. marinum* (Inglis et al., 1993, Belas *et al.*, 1995, Heckert *et al.*, 2001).

Originally *Mycobacterium* spp. were identified by a limited number of phenotypic characteristics which led to variability in diagnosis (Gauthier & Rhodes, 2009). With the advancement of diagnostic techniques there has been documentation of an increasing number of *Mycobacterium* spp. infecting fish (Kaattari *et al.*, 2006; Gauthier and Rhodes, 2009). Mycobacteriosis is not typically associated with large-scale mortality in wild fishes, although significant losses attributed to the disease have occurred in aquaculture (Hedrick *et al.*, 1987; Bruno *et al.* 1998). However, these infections have been detected in an increasing number of wild populations (Abernethy and Lund 1978, Daoust *et al.*, 1989, Lansdell *et al.*,1993). While our knowledge has changed dramatically, the impacts of mycobacteriosis are still inadequately understood for most wild populations (Heckert *et al.*, 2001).

## Methods

Hungry Horse Reservoir is an impoundment of the South Fork Flathead River in the upper Flathead drainage, Northwest Montana (Figure 1). The dam creating the impoundment is 564 feet tall, and is the 10th tallest dam in the United States. The resulting reservoir is 34 miles long and covers 23,800 surface acres. The dam acts as a large barrier and the associated reservoir and river drainage have largely retained their native fish species assemblage. This system is home to one of the only

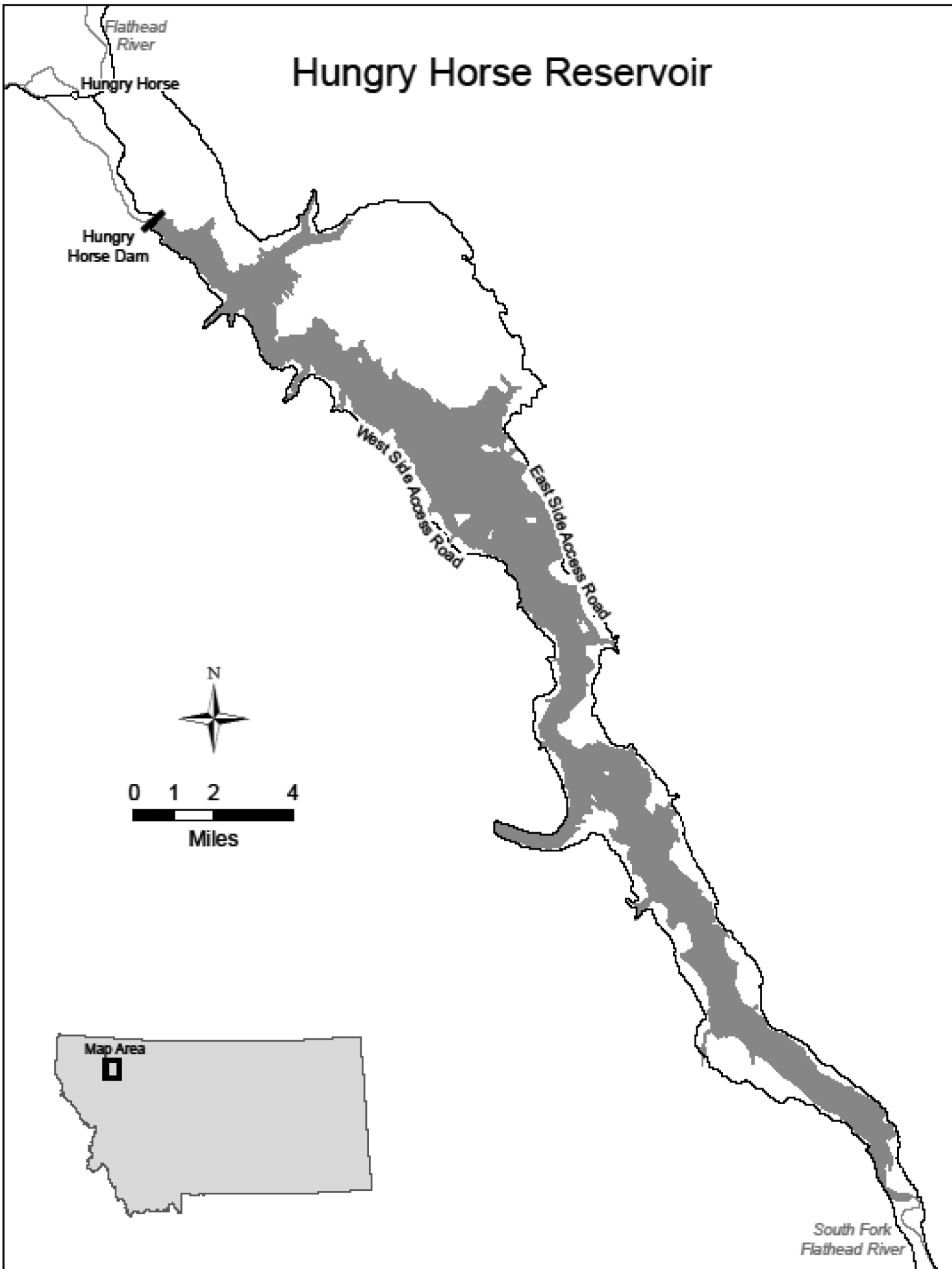


**Figure 1.** Hungry Horse Reservoir, where the angler caught the infected bull trout

remaining prosperous bull trout populations, a species listed as threatened under the Endangered Species Act, in the contiguous 48 states and is currently the only location bull trout can be legally harvested in Montana.

An angler-caught bull trout was brought in to the Kalispell area office of Montana Fish, Wildlife & Parks (MFWP) in June of 2009. This fish was in noticeably poor condition and was examined internally and externally for gross pathology. Upon noticing many large nodules in the liver, the fish (Figure 2) was frozen and sent to the MFWP Fish Health Lab for further diagnosis. Upon receipt at the Fish Health Lab the specimen was again examined grossly and tissue smears and imprints were obtained. Portions of kidney, liver and spleen were both Gram stained and acid-fast stained using a TB Quick Stain kit (Becton Dickinson; Franklin Lakes, New Jersey). Upon detection of acid-fast rods, a portion of the liver was preserved using Davidson's fixative and sent to the Washington Animal Disease Diagnostic Laboratory (WADDL) for further identification.

Upon receipt at WADDL, four grossly representative sections of the submitted liver were trimmed, dehydrated through graded ethanol processing and embedded in paraffin wax blocks for histological analysis. Paraffin wax blocks were sectioned at 4 µm and the resulting sections stained with routine hematoxylin and eosin or a Kinyoun's acid-fast stain (Gibson Laboratories; Lexington, KY). After confirmation of acid-fast bacteria consistent with MFWP findings from gross examination and impression smears the imbedded tissue was submitted for molecular diagnostic testing to more specifically identify the bacteria. Samples were screened for the presence of mycobacteria by utilizing conventional PCR and sequencing of the genus specific region of the ribosomal 16S-23S intergenic transcribed spacer (ITS) region. The sequencing and analysis of this region has been validated as suitable targets for mycobacterial identification and the 16S-23S ITS region possesses greater sequence variation than the 16S rDNA (Mohamed, *et al*., 2005). This provides a greater ability for mycobacterial species differentiation between genotypically similar bacteria (Ngan *et al*., 2011). DNA was extracted from the paraffin block using a Qiamp DNA Mini-kit (Qiagen; Valencia, CA). The extracted DNA was used as a template for PCR amplification using *Mycobacterium* genus-specific primers to amplify a portion of the 16S-23S rRNA internal transcribed spacer (ITS) region as previously described (Roth *et al*., 2000). Primers Sp1 (5'-ACC TCC TTT CTA AGG AGC ACC-3') and Sp2 (5'-GAT GCT CGC AAC CAC TAT CCA-3') were used, yielding a 225 base pair amplicon. The PCR conditions entailed 5 min of denaturing at 94°C, followed by 35 amplification cycles consisting of 1 min of denaturing at 94°C, 1 min of annealing at 58°C, and 1 min of extension at 72°C, with a final extension cycle of 7 minutes at 72°C. Extracted DNA from *M. avium* was used as a positive control. Water was extracted and run as a negative extraction control. The PCR amplicons were visualized on a 1.5% agarose gel containing ethidium bromide, excised using a sterile scalpel blade under UV illumination, and purified using a Freeze 'n' Squeeze kit (BioRAD; Hercules, CA). The amplicon DNA was sequenced directly on both strands by a commercial vendor (Genewiz; South Plainfield, NJ). Forward and reverse sequences were aligned using Clustal W on-line (Thompson *et al.*, 1994). Sequences were compared with previously reported sequences using a BLAST search of GenBank online (NCBI, National Institutes for Health, Bethesda, MD).

## Results

Examination of slides at the MFWP Fish Health Lab was conducted at 1000x using oil immersion. Gram positive and acid-fast bacteria were only seen in the liver impression smears. The bacteria can be characterized as numerous brightly staining, red, short rods (Figure 3).

Histological examination of each of the produced slides of liver revealed numerous randomly scattered granulomas separated by abundant dense fibrous connective tissue interspersed with small to moderately sized aggregates of macrophages and remnant clusters of hepatocytes. The granulomas ranged from 100-700µm in diameter and were characterized by a core of cellular debris and epithelioid macrophages in turn bordered by bands of collagen interspersed with fibroblasts. Serial sections that were stained with a Kinyoun's acid-fast stain revealed numerous bright pink bacilli

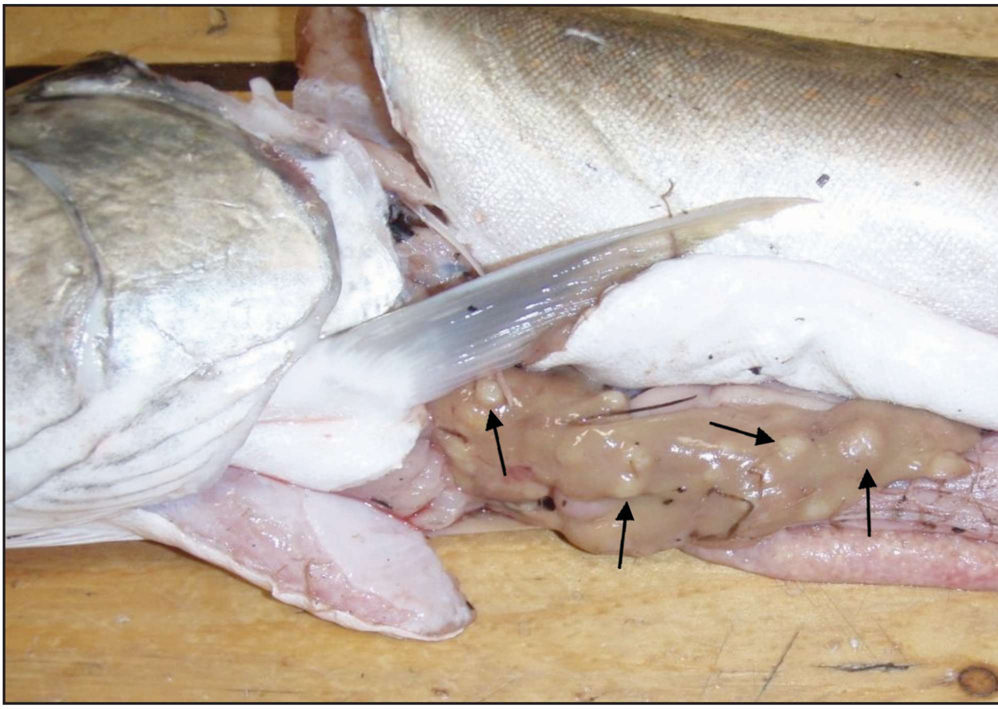

**Figure 2.** Bull trout with noticeable liver nodules (*see* ⟶ ).

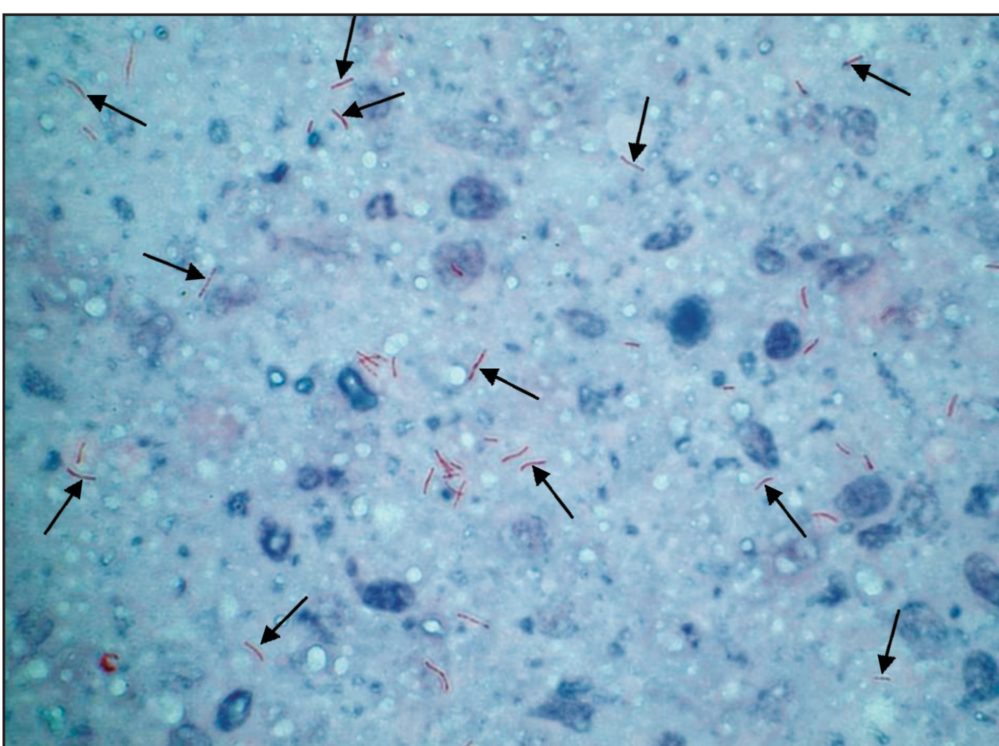

**Figure 3.** Mycobacterium fortuitum rods (*see* ⟶ ) from liver smears, Magnification 1000x (Oil Immersion)

(presumptively *Mycobacterium* spp.) within the cytoplasm of macrophages in the granulomas and scattered within the contiguous connective tissue.

PCR with universal rRNA ITS primers and sequencing of the produced amplicon from DNA extracted from paraffin embedded tissue blocks was performed. The amplified sequence matched *Mycobacterium fortuitum* with 100% sequence identity to GenBank acc #DQ134000.1 when compared to sequences in GenBank and had no other close matches.

## Discussion

*Mycobacterium fortuitum* was first detected from neon tetra (*Paracheirodon innesi*) in 1953 (Ross and Brancato, 1959). It has since been isolated from numerous captive and wild fish (Bragg *et al.*, 1990, Lansdell *et al.*, 1993, Talaat *et al*., 1999, Beran *et al.*, 2006, ) but this detection is an expansion of the current documented extent of this organism. This is a unique finding given the isolation of the fish community from which it came and the uniqueness of the species it was affecting. Hungry Horse Reservoir is the only location in the contiguous U.S. where a bull trout may be legally harvested.

Detection by molecular methods alone wouldn't indicate if disease is present or if the bacteria were viable (Gauthier & Rhodes, 2009). Our diagnosis that acid-fast bacteria were present, along with the presence of DNA and gross clinical signs indicates that this was the pathogenic agent affecting this fish. There have been subsequent efforts to detect mycobacteriosis in Hungry Horse Reservoir. Fish were examined during the fall gill net sets of 2009 ($n$ = 144) and 2011 ($n$ = 98) with no fish of mixed species composition showing clinical pathology consistent with what was seen in the original bull trout specimen. This supports the conclusion that even if *Mycobacterium* DNA was present, it wouldn't be significant without the accompanying disease signs or observable bacteria present in the tissue.

## Acknowledgements

We would like to thank the angler, Cody Schneigert, for bringing this bull trout specimen into our offices for further examination. Thank you to the MFWP Region 1 fisheries crews for bringing this unique case to our attention and collecting fish from Hungry Horse Reservoir for further investigation. Thank you to the diagnostic crews at WADDL for a definitive diagnosis on this unique case. In addition, thank you to Dave Stagliano and Phillip Sawatzki for improving this manuscript through the peer review process.

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# Micro-Habitat Characteristics of Mountain Plover Nest Sites

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## Abstract

This study was conducted on shortgrass prairie in northeast Colorado to determine micro-habitat characteristics of nest sites for mountain plover (*Charadrius montanus Townsend*). Vegetation and soil surface characteristics were sampled in the spring of 1996-97 at and near 16 nests to identify important micro-habitat characteristics for site selection. We collected data on plant structure and canopy cover near nests in the spring during 2 years. Mean bare ground within a 15 m radius of the nest was 24 percent and bare ground patch size was 29 cm$^2$. Mountain plovers selected nest sites that had short plant structure and a mean visual obstruction reading (VOR) of 0.6 cm. Plant structure (VOR) from 4 m to 15 m was significantly greater than structure at 0 to 2 m from the nest.

**Key words:** mountain plover, grazing, habitat, plant height, soil surface, visual obstruction.

## Introduction

The mountain plover (*Charardrius montanus*) is found on level sites with sparse, short vegetation throughout most of its range (Olson and Edge 1985). Bradbury (1918, page 157) described a mountain plover nesting area 20 miles east of Denver as cattle range "…covered with short-cropped buffalo or grama grasses with frequent bunches of dwarfed prickly pear, and an occasional cluster of stunted shrub or weed…". Graul (1975) found most mountain plover nest sites in Weld County, Colorado in shortgrass areas of blue grama (*Bouteloua gracilis*) and buffalograss (Buchloe dactyloides) with scattered clumps of plains prickly pear (*Opuntia polyacantha*) and western wheatgrass (*Pascopyrum smithii*). There is little information focusing specifically on the micro-site characteristic of mountain plover nest sites. The mountain plover was originally proposed as threatened or endangered according to the Endangered Species Act of 1973 in 1999 (Federal Register 2011)in 2002 but was withdrawn from consideration in 2003. In 2010, the mountain plover was again proposed as a threatened species. The proposal to list the mountain plover as a threatened species was withdrawn May 12, 2011. It was determined that the mountain plover was not threatened or endangered throughout all or a significant portion of its range. Though not listed as an endangered species the, mountain plover should receive continued surveillance just to maintain existing populations. The purpose of this study was to determine nest selectivity of mountain plovers by assessing and describing vegetation and soil surface characteristics at, and directly surrounding mountain plover nests in Colorado.

## Study Area

The study area was in northeastern Colorado near Keota in Weld County and within the Pawnee National Grassland., The grassland encompasses 78,162 ha of publicly owned tracts of and intermingled with privately owned farms and ranches. The area is classified as a shortgrass steppe; blue grama, buffalograss, plains prickly pear, western wheatgrass, and sun sedge (*Carex inops*) are the principal plant species (USDA NRCS 2004). Other plant species present included woolly plantain (*Plantago patagonica* Jacq.), rubber rabbitbrush

(*Ericameria nauseosa* [Pall. ex Pursh] G.L. Nesom & Baird), sixweeks fescue (*Vulpia octoflora*), and fourwing saltbush (*Atriplex canescens*). The soil type in the study area is an Ascalon-Vona sandy loam, a deep well-drained Ustollic Haplargid (Crabb 1982).

# Methods

Mountain plovers, in a preliminary search of the study area, were most frequently found on loamy plains range sites with less than 2 percent slope and a southern to southwestern aspect in the study area. We selected 8 sites with these attributes that were 1.6 to 15 kilometers apart and roughly 500 ha in size to search for plover nests. Searching for individual plovers began at sunrise and continued through sunset during the nesting period. Once a plover was located, it was observed until it settled on the nest. The nest was then located and data collected within a very short time. We initially searched the selected sites for mountain plover nests in spring, 1996. Because so few nests were found on the 8 study sites in the spring of 1996, we expanded the search in 1997 to include larger areas outside the original study sites that were potentially good mountain plover habitat.

We measured vegetation height-density (density of leaf mass at various heights determined by visual obstruction readings on a Robel pole) and cover along 15 m transects radiating outward in the 4 cardinal directions from each nest during the nesting period. We recorded the height-density or visual obstruction reading (VOR) of vegetation for each nest site using a modified Robel pole as described by Uresk and Benzon (2007) and Uresk and Juntti (2008). The modified pole had alternating 1.27 cm white and gray rings. Bands were numbered beginning with 0 (white band) at the bottom and the pole was placed on the soil surface. A (VOR) was taken from a distance of 4 m from the pole for each of the four cardinal directions. The lowest visible band was recorded. Visual obstruction readings were recorded at the nest site and at points 10 and 15 m from the nest along each of the four transects. Because 1996 data showed significant differences between the nest and 10 m station, we added additional sample stations at 2, 4, 6, and 8 m from the nest along the transects in 1997 in an attempt to more precisely describe the vegetation zone around the nest.

Canopy cover by major plant species, total grasses, total forbs, total plants and bare ground (Daubenmire 1959) and soil surface characteristics (percent bare ground and bare ground patch size) were estimated within 20 x 50 cm quadrats positioned at 1 m intervals along each of the four 15 m transects. Bare ground patch size within each quadrat was classified into 1 of 6 class codes (Table 1). Mid points of class codes were used to estimate patch size ($cm^2$) following methods described by Daubenmire (1959).

**Table 1.** Class codes (1-6) with corresponding size of bare ground patches. Mid points of patch size were used to estimate area ($cm^2$).

| Class codes | Bare ground patch size ($cm^2$) |
|---|---|
| 1 | 0 - 3.2 |
| 2 | 3.3 - 12.6 |
| 3 | 12.7 - 28.3 |
| 4 | 28.4 - 50.3 |
| 5 | 50.4 - 78.6 |
| 6 | >78.6 |

VOR data at the nest site and along the transects at various distances (meters) were analyzed with a General Linear Model repeated measures design (SPSS, 2003) for both years. The Bonferroni pairwise comparisons test was used to determine significance differences between VORs at the nest site and at distances from the nest. We used a two sample T-test to compare differences between years for canopy cover variables and patch size at $p = 0.10$.

# Results

Sixteen nests were located during the 2 years of sampling: 6 in 1996 and 10 in 1997. Mean VOR at time of nesting for 6 nest sites in 1996 was 0.9 cm ± *SE* 0.3 and for 10 nest sites in 1997 VOR was 0.3 ± *SE* 0.2. Bare ground, bare ground patch size, and canopy cover of major plants and categories within the 15 m radius of the nest is shown in Table 2 for both years. Differences ($p$ = 0.10) were observed between years for blue grama, total cover and total graminoids with 1996 providing greater canopy cover than in 1997. Overall, bare ground was 24% ± SE 2%, bare ground patch size 29 $cm^2$ ± *SE* 3cm, total plant cover 69% ± *SE* 3%, total graminoides 67% ± *SE* 3% and total forbs 4% ± *SE* < 1%.

VOR was greater at stations away from the nest. For combined years, mean VOR at the nest station (0.06 ± *SE* 0.2 cm) was significantly less than VOR at both 10 m (1.8 ± 0.3 cm) and 15 m stations (2.0 ± 0.3 cm) ) ($p$ = 0.05). In 1997, VOR's estimated at 10 nests sites and at 2 m away from the nest were similar (Fig. 1, $p > 0.10$). However, mean VOR at the 4 m station and beyond to the 15 m were similar but significantly greater than at or less than 2 m of the nest $p$ = 0.10 (Fig. 1).

## Discussion

Mountain plovers prefer areas that have been intensively grazed by livestock and avoid areas of vegetation greater than 0.5 cm high for nesting (Graul and Webster 1976; Leachman and Osmundson 1990). Micro-site characteristics were important to mountain plovers nesting on the Pawnee National Grassland. With a refinement of the sampling design in 1997, the zone of greatest influence was shown to be a distance of about 2 m compared to distances from 4 through 15 m from the nest. Once an area had been selected for a breeding territory, the vegetation structure, cover, and amount of bare ground were important characteristics of the actual nest site location by mountain plovers.

Visual obstruction readings at the nest site were slightly greater (0.57 cm) in our study in Colorado compared to values (0.13 cm) reported by Parrish et al. (1993) in Wyoming. In Colorado on shortgrass prairie, plover nests were found in blue grama, buffalograss, and western wheatgrass grazed by cattle. Nesting sites were located in areas with 24 percent bare ground distributed in an average patch size of 29 $cm^2$. Olson and Edge (1985) reported 27 % bare ground (erosion pavement) for nest sites in Montana. However, Parrish et al. (1993) and Plumb et al. (2005) reported

**Table 2.** Vegetation and soil surface characteristics measured within a 15 m radius of Mountain Plover nests on the Pawnee National Grassland for years 1996-1997 and years combined for 16 nest sites.

| Plant species | Mean ± SE (n = 6) 1996 % | Mean ± SE (n = 10) 1997 % | Mean ± SE (n=16) 1996-1997 % |
|---|---|---|---|
| *Pascopyrum smithii* | 8.0 ± 3.2[a] | 5.7 ± 2.4 | 6.6 ± 1.9 |
| *Bouteloua gracilis* | 23.0 ± 7.1 * | 41.5 ± 5.9 | 34.6 ± 5.0 |
| *Buchloe dactyloides* | 38.3 ± 3.6 | 22.9 ± 7.9 | 28.7 ± 5.4 |
| *Opuntia polyacantha* | 6.5 ± 1.7 | 8.7 ± 1.9 | 7.9 ± 1.3 |
| Total cover[b] | 76.8 ± 1.7 * | 63.7 ± 3.6 | 68.6 ± 2.8 |
| Total graminoids | 76.3 ± 1.6 * | 53.1 ± 6.7 | 67.2 ± 2.8 |
| Total forbs | 4.3 ± 1.3 | 3.8 ± 0.3 | 4.0 ± 0.5 |
| Bare ground | 21.8 ± 2.4 | 26.0 ± 2.7 | 24.4 ± 2.0 |
| Bare ground patch size ($cm^2$) | 25.7 ± 3.8 | 30.6 ± 3.9 | 28.8 ± 2.8 |

[a] Standard error

[b] Two dimensional cover that does not include the sum of individual species.

[*] Significantly different between years at p = 0.10

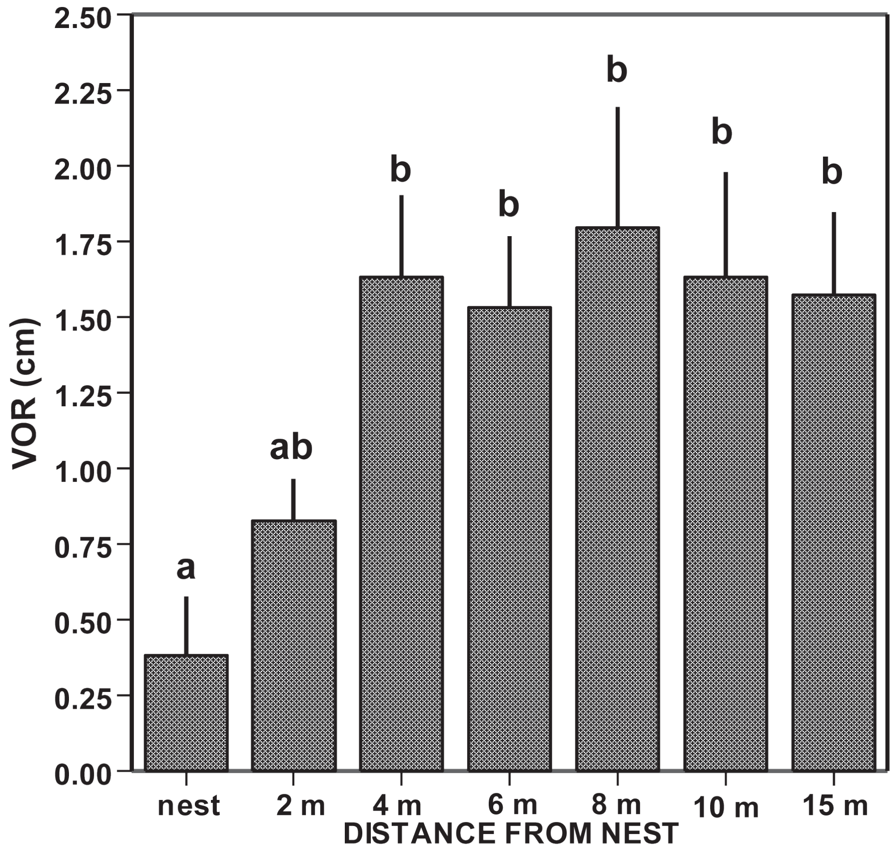


**Fig. 1.** Visual obstruction readings (VOR) at different distances away from mountain plover nests ($n = 10$) in Colorado for 1997. Different letters above the bars represent differences among the distances (m) at $p = 0.10$ with standard errors.

nesting at areas of 72% and 47% bare ground, respectively, on grasslands in Wyoming.

Livestock grazing has been used as a tool for wildlife habitat management (Severson 1990). Grazing management can be an important and perhaps less expensive tool than mowing or prescribed fire for creating or maintaining mountain plover nesting habitat. Prairie dog colonies are important for plover nesting and should receive a high management priority: however, managing and maintaining prairie dog colonies is difficult with continued outbreaks of plague and rodenticide poisoning on the plains (Miller et al. 2007). Grazing management plans related to the amount of herbage remaining after livestock grazing are generally designed for optimal livestock or plant production and often result in homogeneous vegetation structure. To create or maintain optimal mountain plover habitat, grazing intensity should be heavy during fall, winter and early spring. Livestock grazing provides managers with some control for creating favored plover habitat. Creating vegetation areas with VORs with a mean of 0.6 + *SE* 0.2 cm with livestock grazing could provide conditions of height-density structure and patchiness for attracting plovers.

Mountain plovers use grasslands with low canopy cover, high percentage of bare ground and low visual obstruction near nests. Target conditions for optimal nesting habitat for mountain plovers include less than 70 percent total vegetation canopy cover , bare ground of 24 percent or greater and visual obstruction readings of vegetation with averages ranging from 0.3 to 0.9 cm.

Prairie dog colonies and heavy livestock grazing in late fall, winter or early spring provide preferable mountain plover habitat. These guidelines should be beneficial and effective in keeping the mountain plover from being proposed as a threatened or endangered species

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# Effectiveness of Sharp-tailed Grouse Transplants in the Tobacco Valley, Montana

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## Abstract

Records extending back to 1861 document the presence of sharp-tailed grouse (*Tympanuchus phasianellus*) in the Tobacco Valley of northwestern Montana. However, following a similar trend throughout the species' range, populations of sharp-tailed grouse in the Tobacco Valley declined sharply until only three males were observed on one lek by 1987. Seven years of transplanting birds (1987 to1997) increased the numbers of individuals on one lek and led to the establishment of a second lek that persisted for three years. After each of the transplant periods ended, the number of males counted at leks gradually declined until the last lek activity was recorded in 2000. Sharp-tailed grouse in the Tobacco Valley likely were extirpated by 2003.

**Key Words:** Columbian sharp-tailed grouse, *Tympanuchus phasianellus columbianus*, Tobacco Valley Montana, population augmentation, extirpation.

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## Introduction

In Montana, the Columbian subspecies of sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) occurs west of the Continental Divide (Connally et al. 1998). This subspecies has experienced a 90% decline in historically occupied habitat (Miller and Graul 1980, U.S. Fish and Wildlife Service 2000), and was identified as a highest priority species in need of management in Montana's Comprehensive Fish and Wildlife Conservation Strategy (Montana Fish, Wildlife & Parks 2005).

The first written record of sharp-tailed grouse in the Tobacco Valley in northwestern Montana appeared in the journals of members of the British Boundary Commission charged with surveying the 49th parallel after it was established as the boundary between Canada and the United States. John Keast Lord, Assistant Naturalist and Veterinary Surgeon for the British Boundary Commission in 1861, reported the sharp-tailed grouse to be "particularly abundant on the tobacco plains near the Kootanie River" near present day Eureka (Thompson 1985). In 1866 Lord authored a book that contained perhaps the first detailed, accurate description of leks and the spring mating rituals as well as illustrations of the sharp-tailed grouse in Montana (Lord 1866).

Subsequent reports of sharp-tailed grouse continued to document the species presence in western Montana. Siloway (1901) reported that sharp-tailed grouse occupied grasslands west of the Continental Divide in Montana. Saunders (1921:58) stated that sharp-tails were a "fairly common permanent resident of the mountain valleys, formerly very common but becoming rarer each year." However, by 1969, sharp-tails were confined to small areas in the Kootenai, Flathead, and Blackfoot river valleys (Hand 1969). The last reported sighting on the Flathead Indian Reservation was in the late 1970s (Brett Gullet, personal communication) until May 2008 when Dwight Bergeron of Montana Fish, Wildlife & Parks observed a single bird in the Camas Prairie Basin (Dwight Bergeron, personal communication). The last documented sighting in the Flathead Valley was made during an Audubon Christmas Bird Count in 1980 (Leo Keane, personal communication). In the Blackfoot Valley, a total of 14-16 birds were documented on two leks in the mid-1990's (Deeble 1996), but by April 1999, only five males were observed on the two leks (D. Lewis Young, personal observation).

The first recorded lek survey was conducted in 1960 by the Montana Fish and Game Department, now called Montana Fish, Wildlife & Parks (Manley and Wood 1990). Then from 1966-1974, Montana Fish and Game conducted irregular surveys on the leks in Sections 11 and 26. From 1976-1980, professor Chuck Jonkel and students from the University of Montana conducted surveys in the valley. From 1979 until present, the lek surveys have been conducted by a combination of people and agencies and organizations including Montana Fish, Wildlife & Parks, Montana Natural Heritage Program, The Nature Conservancy, Kootenai National Forest, and private individuals. The senior author has counted the leks annually beginning in 1987.

In the Tobacco Valley of northwestern Montana, declining lek counts in the 1970s and 1980s led to efforts to sustain or increase the Tobacco Valley population through transplants. This decision was based on observations that most attempts to reestablish extirpated populations failed (Toepfer et al. 1990). The purpose of this paper is to summarize those transplant efforts and evaluate their effectiveness.

## Study Area

The Tobacco Valley is located in northwestern Montana near the town of Eureka (48.945° North, -115.076° East, Figure 1). The Kootenai River drains the valley which is surrounded by the Salish Mountains to the west and south and the

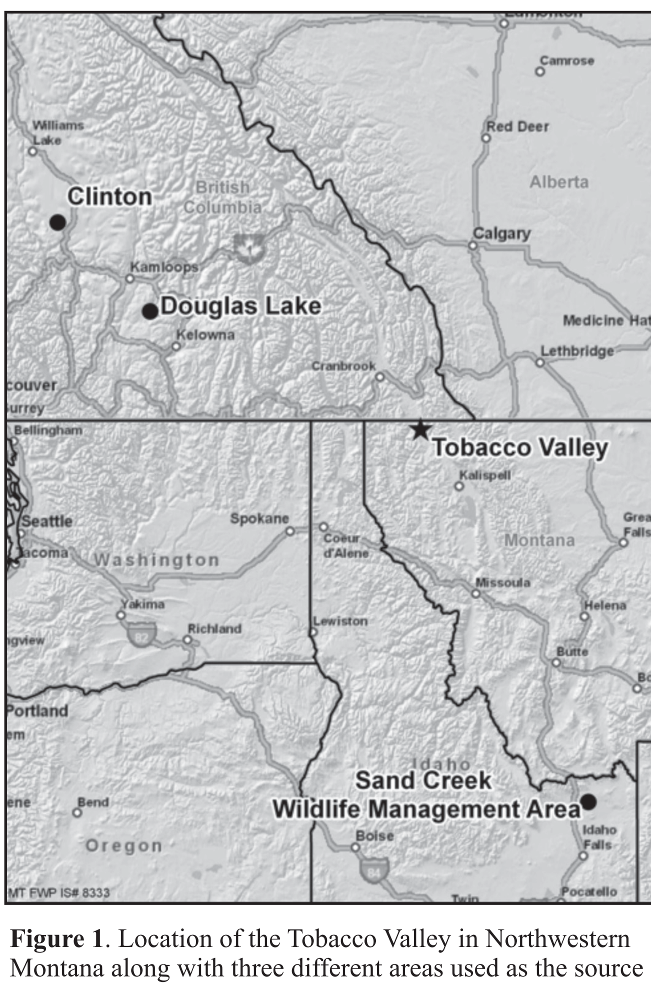


**Figure 1**. Location of the Tobacco Valley in Northwestern Montana along with three different areas used as the source of transplanted sharp-tailed grouse; Sand Creek Wildlife Management Area, ID, Clinton, BC, and Douglas Lake, BC.

Galton Range and Whitefish Range to the east. Vegetation in the valley floor was historically dominated by bunchgrass communities resulting from limited precipitation caused by a rain shadow effect from the surrounding mountains and recurring fires from both lightning starts and cultural use by the native Ktunaxa First Nation people. Average annual precipitation in the valley is 37 cm. Low temperatures in January average -9.1°C and high temperatures peak in July at 29.4°C (Western Regional Climate Center 2011). The geography of the valley is dominated by drumlins and kettles formed by glacial action (Coffin et al. 1971).

Bown (1980) reported six leks in the Tobacco Valley prior to the initiation of this transplant effort. However, only five of those six locations were mapped, and historic lek count data were available from only three of the mapped locations. Another lek was discovered in 1991 bringing the total number of leks with data to four (Figure 2).

## Methods

### Source of Transplanted Birds

Two areas in British Columbia, Canada, and one in Idaho (Figure 1) were the sources for transplanted sharp-tailed grouse. All birds transplanted to the Tobacco Valley

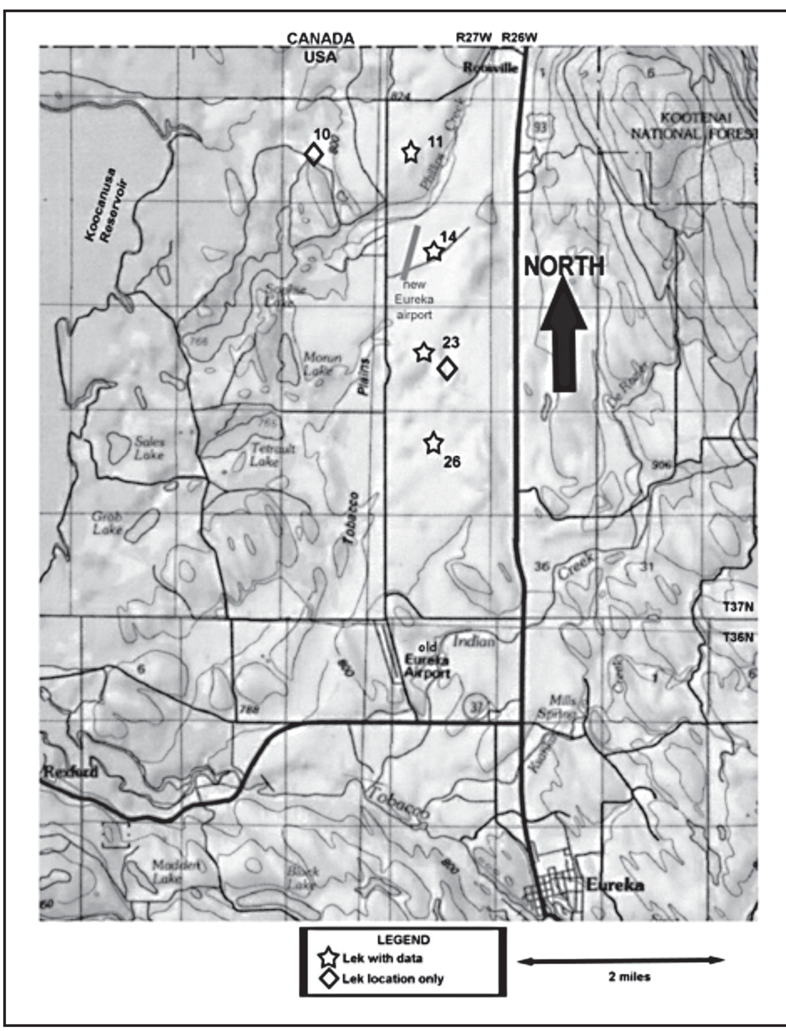


**Figure 2.** Documented lek locations in the Tobacco Valley, Montana 1960-2000.

were Columbian sharp-tails from three areas of distinctly different habitat types. From 1987-1991, 64 transplanted birds (50 males, 14 females) came from Douglas Lake, B. C., Canada (Figure 1). Douglas Lake is primarily an area of rolling grasslands with habitat very similar to the floor and foothills of the Tobacco Valley.

In 1991, two males and four females were transplanted from the Sand Creek Wildlife Management Area in southeast Idaho (Figure 1) where the dominate habitat was sagebrush.

In 1996-1997, 52 males and 17 females were transplanted from near Clinton, B.C., Canada, (Figure 1) where the habitat was recently-clearcut lodgepole pine forests with interspersed wet meadows. The clearcuts were very large, measuring tens or hundreds of square kilometers for individual cutting blocks.

## Transplant Techniques

Initially drop nets were deployed over the lek to capture grouse to be transplanted. Although drop nets proved very successful, they also required considerable equipment and time to set up. Subsequent trapping efforts involved walk-in traps deployed in either the wing trap or circle trap configuration (Toepfer et al. 1988), depending on the size of the lek and the topographical features.

A total of 139 birds (Table 1) were captured in the spring then transported to the Tobacco Valley and released on the Section 26 lek. The first two years, 1987 and 1988, all captured birds were flown in small aircraft directly to the Eureka airport. In 1989, the first group of captured birds were flown directly to Eureka and the second group was flown to an airstrip near Elko, B.C., about 32 km north of the international border, then transferred to vehicles for the trip into the U.S. Beginning in 1990, all captured birds were transported on the ground in vehicles (a total of 780 km from Douglas Lake and 825 km from Clinton to the Tobacco Valley release site). Multiple trips were made as needed to insure that transplanted birds were released less than two days after capture. Captured birds were placed individually in one of four compartments in divided cardboard boxes with adequate ventilation. Water was initially provided to birds during transport, but was later discontinued because there was no evidence that any birds consumed any water during transport. Only one mortality occurred during transport during the seven years of transplants.

Table 1. Numbers, dates, and sources of sharp-tailed grouse released on the Section 26 lek, Tobacco Valley, Montana, 1987-1997.

| Year | Sex | | Total | Radio Marked | Source | Survival |
|---|---|---|---|---|---|---|
| | Male | Female | | | | |
| 1987 | 14 | 0 | 14 | | | |
| 1988 | 18 | 0 | 18 | | | 47% for 1 year |
| 1989 | 4 | 9 | 13 | | Douglas | after transplants |
| 1990 | 11 | 5 | 16 | 7M 5F | Lake, B.C. | for several |
| 1991 | 3 | 0 | 3 | | | cohorts |
| 1991 | 2 | 4 | 6 | 2M 4F | Idaho | 0% after 30 days |
| 1996 | 19 | 6 | 25 | 4M 5F | . | 10.5% and 6% for 1 year |
| 1997 | 33 | 11 | 44 | 9F | Clinton, B.C | after transplants |
| **Total** | **104** | **35** | **139** | | | |

Before release all birds were leg banded with numbered plastic leg bands that were also colored coded by sex and year. Forty birds received radios in order to monitor their locations and survival after release. The radio transmitters were made by Holohil Systems Ltd, Ontario, Canada, weighed approximately 11 grams, and were a necklace style attached by an elasticized small-diameter cord around the neck. Birds were then placed in custom built release boxes. Each box had six compartments and a sliding door that covered all compartments. Each compartment measured 20x20x33 cm and had several holes for ventilation. A string was attached to the sliding door and led to a tent 5-10 m away that was used as a blind. The string was slowly pulled to open one compartment at a time (Figure 3).

Evening was the preferred time to release birds because newly released birds would not have time to move very far before dark, thus giving them more time to settle down after the transport and release. All but three releases were done in the evening between sundown and dark. Birds were placed in the release boxes near the lek less than one hour before sundown. If possible, releases were made after local birds appeared on the lek. Birds were released one at a time so that each bird's actions could be observed.

To provide an auditory signal to newly released birds that the release site was an active lek, a continuous loop recording of sharp-tail vocalizations was played on a battery-powered stereo system with external weather-proof speakers. A timer was set to play the recording for approximately 1.5 hours beginning just before daylight in the morning and again for approximately one hour just before dark in the evening. The recorded sharp-tail vocalizations were played from the time of the first transplant of the season until the end of the normal lek attendance even if there were males attending the lek and displaying. In 1996, only one male appeared on the lek in early spring and he had disappeared before the transplants began, so eight silhouette sharp-tail decoys were deployed in an attempt to add a visual signal to the newly transplanted birds.

After each transplant, multiple visits were made to the lek to observe and record numbers of birds at the lek. Attempts were made to observe leg band colors, but color was often difficult to determine for many of the birds due to the height of grass on the lek. When radio-marked birds were present, a Telonics receiver and hand-held H-antenna were used to obtain locations and confirm the identity of each bird.

**Figure 3.** Release box and arrangement with tent blind on the Section 26 lek.

## Lek Surveys

Leks were surveyed an unknown number of times per year from 1960-1986. During that period, except 1979-1980, observers would typically make a brief observation of the lek noting the number of birds observed, and then would flush birds to make a more accurate count. If females were present they were included in the total count of flushed birds. The lek count recorded for each year was the highest number of birds seen on the lek at one time (males and females combined). During 1979-1980 and 1987-2010, the reported lek count for each year was the highest number of males seen at one time based on multiple visits (approximately 5-15). In those years that transplants took place, the reported lek counts are the highest number of males observed on the leks before transplants took place. Numbers of individuals observed on a lek after a transplant was often considerably higher than before a transplant.

# Results and Discussion

The number of individuals on leks increased from an initial count of 14 birds in 1960 to a peak of 54 total birds on all leks in 1971, and subsequently decreased to the last observation of two males observed in spring 2000 (Figure 4). Numbers of birds on the Section 26 lek increased after both the 1987-1991 and 1996-1997 transplants. A new lek was also documented in Section 14, five years after the initial 1987 transplant and about 2.5 km north of the Section 26 lek (Figure 2). Not only did the transplanted birds attend the leks the same year of transplant, many survived one or more years and continued to attend the leks. After the first two years of transplants, the number of males on the Section 26 lek increased from three to 8-10 and maintained that level for six years, including three years after the first series of transplants ceased in 1991. During that same time period, the new Section 14 lek was active with a peak of 12 males in 1991, the year it was discovered.

Use of the Section 14 lek began decreasing in 1992, one year after the first series of transplants stopped, and this lek was unoccupied three years post-transplant. Observations of some marked birds on the Section 14 lek, which were originally released on the Section 26 lek, suggested that the Section 14 lek was indeed a new site that may have been established by surplus birds resulting from the first series

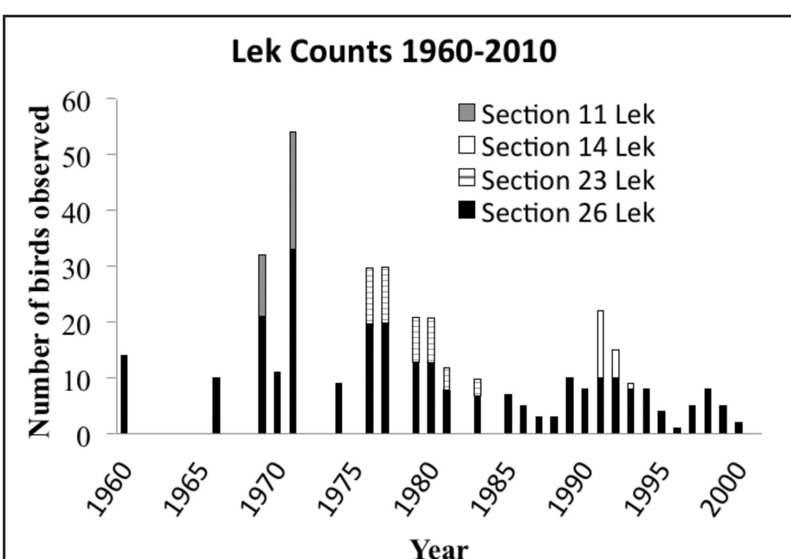


**Figure 4.** Counts of sharp-tailed grouse observed on four leks in the Tobacco Valley, Montana, 1960-2000. Surveys were conducted but no birds have been observed since 2000.

of transplants. The fact that the number of birds at the Section 26 lek remained relatively stable while the Section 14 lek was declining, then attendance at the Section 26 lek continued to decline at about the same pace until the next series of transplants caused another temporary increase in lek use also suggests that the Section 14 lek was established as a result of new birds being added to the valley and either moving to a new lek or displacing some resident birds to create a new lek.

The second series of transplants (1996-1997) resulted in a trend similar to that on the leks in Sections 14 and 26 in the first series of transplants, but the increase of males on the lek was smaller with the birds from Clinton, B.C. After the last transplant in 1997, the numbers peaked in 1998, then began to decline. The last lek activity in the Tobacco Valley was recorded in 2000 (two males). Note that the transplanted birds in 1996-1997 came from clear-cut lodgepole pine habitat and not grasslands like those from the 1987-1991 transplants. This habitat difference may help explain the poorer response observed in the second series of transplants.

Differential rates of survival were observed based on the source of birds (Table 1). Transplanted birds from Douglas Lake experienced 47% survival one year after transplant for several of the transplanted cohorts (Cope 1992). All six birds from southeast Idaho were radio-marked and none survived longer than 30 days (D. Lewis Young personal observation). Survival of birds from Clinton, B.C. was much lower than the Douglas Lake, B.C. birds. Of the 19 males released in 1996, a maximum of two (10.5%) were observed on the lek in 1997 and none in 1998. Of the 33 males released in 1997 a maximum of two (6%) were observed in 1998 and one in 1999 (D. Lewis Young personal observation).

## Conclusions

These data suggest that the two series of transplants may have maintained sharp-tails in the Tobacco Valley for about 12-13 years longer than had no transplants occurred. It is likely that, with only three males on the Section 26 lek in 1987, it would have disappeared by 1988 or 1989. Sharp-tailed grouse populations seemed to respond favorably following each transplant, but after each of the transplant periods ended, the lek numbers gradually declined until the last lek activity was recorded in 2000. Some sharp-tails may have persisted in the Tobacco Valley, but the population was likely extirpated by 2003 since no sharp-tailed grouse sightings have been confirmed in the valley from 2003 through 2012. Many factors may have influenced sharp-tail habitat and populations in the Tobacco Valley (Manley and Wood 1990); but ultimately, efforts to sustain the species by supplementing the population through transplants were unable to overcome whatever factors ultimately led to the extirpation of this population.

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# Wildlife as Biosamplers: Contaminants in Hair of Elk Harvested Near the Anaconda Smelter Site

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## Abstract

The purpose of this research was to test a new way of investigating biological uptake of smelting-related contaminants with a focus on harvested wildlife. Specific objectives were 1) to collect hair samples from elk (*Cervus elaphus*) harvested in the vicinity of the Anaconda Smelter National Priority List Site in Montana, 2) to analyze the samples using inductively coupled plasma – mass spectrometry (ICP-MS), and 3) to identify potential elements of concern from the data. Hair samples were collected from 56 elk, and concentration data were processed using a hazard quotient/index approach based on concepts commonly used in fields of ecological and human health risk analyses. Arsenic concentrations in the hair decreased as a function of increasing distance from the Anaconda smelter stack, and 57 % of the elk sampled were identified as animals of concern. For elk harvested within 25 km of the stack, elements of concern were aluminum, arsenic, barium, boron, lithium, manganese, molybdenum, strontium, and vanadium. For elk harvested within 76-101.5 km of the stack, elements of concern were aluminum, barium, boron, lithium, and manganese. Hazard indices for uranium, arsenic, cadmium, and lithium were larger by factors of ~17, 9, 7, and 6, respectively, for elk harvested within 25 km of the stack compared to hazard indices for elk harvested within 76-101.5 km.

**Key Words:** arsenic, pollution, biomonitoring, hair samples.

## Introduction

For more than a century, smelting activities in Anaconda caused wide-spread contamination in Montana. The United States Environmental Protection Agency (USEPA) listed the Anaconda Smelter Site on the Superfund National Priorities List (NPL) in 1983 (USEPA 1998). As a part of the Superfund activities, several contaminants have been characterized, risks to human health have been estimated, and some cleanup has taken place. Unfortunately, few data have addressed biological uptake of contaminants by human or wildlife populations.

During the past decade, we developed and tested a new way to study contaminant uptake using domestic pets as bioindicators of environmental conditions in Butte and Anaconda (Peterson and Madden 2006). The technique involved sampling the hair of domestic dogs (*Canis lupus familiaris*) and cats (*Felis catus*), analysis by inductively coupled plasma-mass spectrometry (ICP-MS), and identification of elements of concern with a hazard index approach similar to methods employed in the field of risk analysis. More than 400 samples from the domestic pet population identified eight elements of concern (aluminum, arsenic, boron, lead, lithium, manganese, molybdenum, and selenium) in residential neighborhoods of Butte and Anaconda (Madden 2006, Barry 2006, Peterson and Barry 2006, and Robertson 2007).

Similar to our previous field campaigns, the overall goal of the research presented in this paper was to improve understanding of biological uptake of environmental contaminants. Instead of domestic pets, however, we addressed harvested wildlife. Specifically, we targeted the local elk (Cervus elaphus) population, and objectives were 1) to collect hair samples from elk harvested in the vicinity of the Anaconda Smelter NPL Site, 2) to analyze the samples with ICP-MS, and 3) to identify potential elements of concern from the data.

## Uptake of Contaminants by Resident Wildlife

As part of remedial investigation/ feasibility studies of the Anaconda Smelter Site, numerous sampling campaigns were conducted to characterize risk and burden of pollutants on the surrounding environment (USEPA 1998). Few studies, however, were performed to characterize exposure and uptake of these contaminants for resident wildlife species, nor to monitor the efficacy of environmental cleanup. Initial assessment of ecological risk used a simple, predictive food chain model (USEPA 1998) without direct consideration of wildlife. Following the initial assessment, a handful of projects addressed contaminants in small mammals and avian species (Hopper et al. 2002). From recreational and wildlife management viewpoints, however, large mammal populations in the vicinity of the Anaconda Smelter Site were neither sampled nor monitored.

## Hair Samples as Biosamplers of Environmental Exposure

We were the first to propose domestic pet hair as a unique tool for studying residential exposure to mining-related contaminants (Peterson and Madden 2006). In human populations, however, hair and toenails have been used for many years in the field of forensics to determine possible cause of death by ingestion of toxic metals and/or medicines (Chatt and Katz 1988). Likewise, human hair samples have been used by law enforcement and by employers as evidence of illegal drug and alcohol use (Pragst and Balikova 2006).

Elements in the bloodstream of mammals are transferred from the root cells into the hair shaft during growth stages (Beernaert et al. 2007). Hair consists of keratin with cysteine sulfhydryl groups capable of binding to metals and other elements (Mandal and Suzuki 2002). Siedel et al. (2001) and others presented uncertainties about external contamination, but Hinwood et al. (2003) concluded hair sampling to be a good "screening-level" technique for studying environmental exposure if care is taken to properly handle, rinse, and analyze the specimens.

In addition to our research in Butte and Anaconda, field campaigns elsewhere have been advancing the legitimacy of hair sampling as a research tool. Rashed and Soltan (2005), for example, analyzed hair of goats (*Capra hircus*), sheep (*Ovis aries*), and camels (*Camelus*) in Egypt, and concentrations of cadmium, cobalt, iron, lead, manganese, and nickel in the hair correlated to contaminants in vegetation consumed by the animals. D'Have et al. (2009) linked concentrations of lead and cadmium in hair of European Hedgehog (*Erinaceus europaeus*) to contaminant concentrations in the soil. Mercury concentrations were studied in hair of wild boars (*Sus scrofa*) by Sobanska (2005), in hair of deer mice (*Peromyscus maniculatus*) by Waring and Douglass (2007), and in hair of sled dogs by Dunlap et al. (2007). Beernaert et al. (2007) found linear relationships of lead and cadmium among hair, kidney, and liver samples in the Wood Mouse (*Apodemus sylvaticus*). McLean et al. (2009) also linked concentrations of lead and cadmium in soil with hair concentrations from small mammals residing near a decommissioned lead and zinc smelter in Australia. Finally, pollution in Nairobi, Kenya, was studied using hair samples from residential pets and wildlife (Mwaniki 2007). Prior to results summarized here, however, no data were available for wild game species residing on or near contaminated Superfund sites in the United States.

## Methods

As described in more detail by Gillespie (2011), we conducted field campaigns in the Anaconda, Montana area during two hunting seasons (October-November of 2009 and October-November of 2010). In 2009, we collected hair samples from wild game at the Montana Fish, Wildlife and Parks (FWP) hunting check station located along Mill Creek. In 2010, we obtained samples at the Mill Creek check station and at another FWP check station in Divide, Montana. Both stations were selected based on elk populations commonly harvested in the vicinity of the Anaconda Smelter NPL Site.

Regarding experimental protocol, we completed a questionnaire for each animal in our study. Specimens were assigned identification numbers. Hunters were also asked in which hunting districts and drainages the animals were harvested. Other information, such as sex and approximate age of the animal, was documented (Gillespie 2011).

Hair samples, ~ 150 milligrams (mg) in size, were removed from the harvested animals' coats with clean stainless steel scissors. When possible, the hair sample was collected from the region between the shoulder and neck of the animal. Samples were sealed in contaminant-free envelopes and stored until the end of each hunting season when they were sent to Trace Elements, Incorporated (Addison, Texas). Hair was examined with a microscope and rinsed repeatedly with de-ionized water to remove external soil particles prior to analysis by inductively coupled plasma-mass spectrometry. Trace Elements, Incorporated, is a licensed, certified clinical laboratory.

We analyzed the concentration data using the hazard index technique of Peterson and Madden (2006). The method is based on concepts commonly used in the fields of ecological and human health risk analyses. A hazard quotient ($HQ_{ij}$) of element $i$ for animal $j$ was calculated as:

$$HQ_{ij} = \frac{C_{ij}}{RfC_i} \qquad (1)$$

where $C_{ij}$ was concentration of element i in the hair sample of animal j; and $RfC_i$ values were the same reference concentrations used in our other research projects (TEI 2005, Peterson and Madden 2006, Madden 2006, Barry 2006, and Robertson 2007).

In addition to hazard quotients, two hazard indices were examined. A normalized animal hazard index ($HI_j$) was calculated by summing the hazard quotients across the elements:

$$HI_j = \frac{\Sigma_{i=1}^{i=M} HQ_{ij}}{N} \qquad (2)$$

where $N$ was the number of elements. Likewise, a normalized element hazard index ($HI_i$) was calculated by summing the hazard quotients across the number of samples:

$$HI_i = \frac{\Sigma_{j=1}^{j=M} HQ_{ij}}{M} \qquad (3)$$

where $M$ was the total number of animals sampled. As per the method of Peterson and Madden (2006), the target value was 1.0 for both $HI_j$ and $HI_i$. Animals with $HI_j$ values ≥ 1.0 were defined as animals of concern, and elements with $HI_i$ values ≥ 1.0 were defined as elements of concern.

## Results

During field campaigns in 2009 and 2010, we collected hair samples from 56 elk harvested in the vicinity of the Anaconda Smelter NPL Site (Fig. 1). Harvest locations of the elk in the study corresponded to distances ranging 7.5-101.5 km from the Anaconda smelter stack, and our dataset consisted of hair samples from 31 adults, 25 sub-adults, 28 males, and 27 females (Table 1). Adult elk in this project were defined

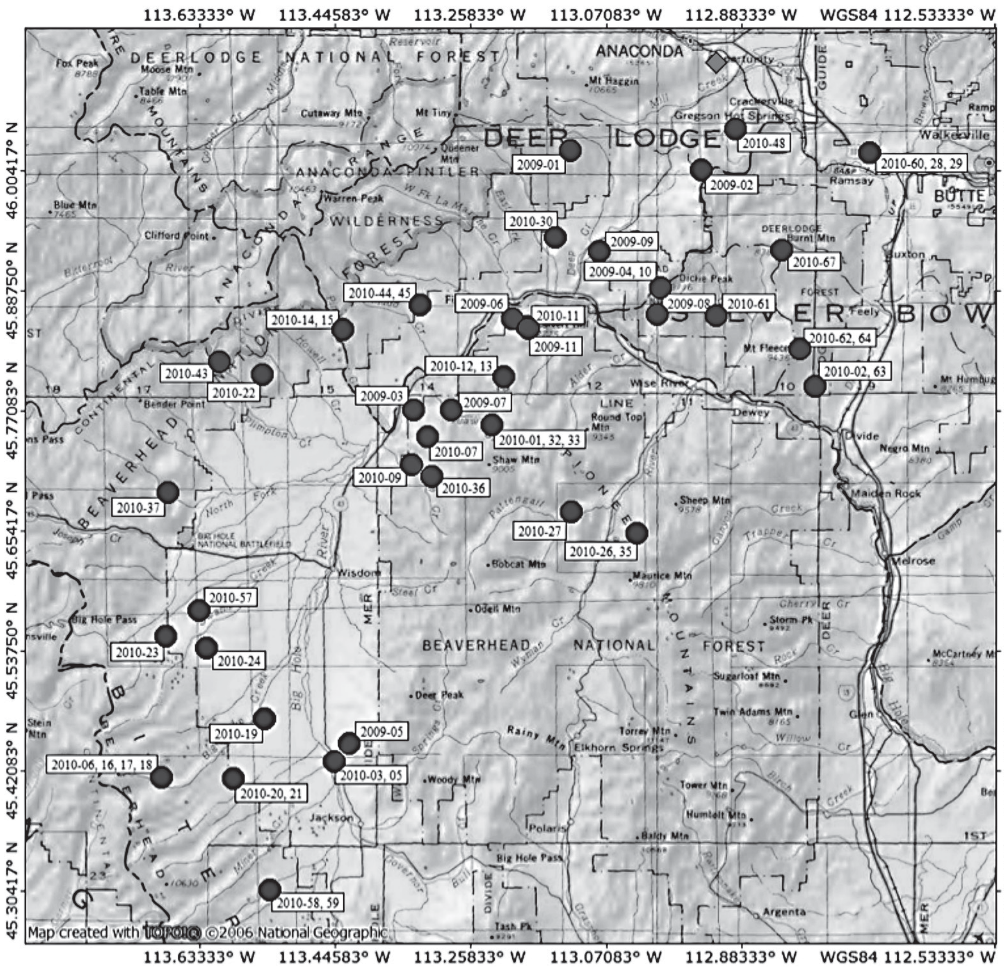


**Figure 1.** Map of harvest locations (circles) for 56 elk sampled during field campaigns in 2009 and 2010. The Anaconda smelter stack is represented by a diamond, and harvest locations are labeled with sample identification numbers. As a scale of reference, the distance between the stack and harvest location is 19.1 km for Sample 2010-28, and the corresponding distance is 101.5 km for Sample 2010-59.

as 3 years of age and older, and sub-adults were younger than 3 years.

Concentrations of arsenic in the elk hair decreased as a function of increasing distance from the stack (Fig. 2). Thirty-six (~ 64 percent) of the samples contained arsenic concentrations greater than a reference concentration of 0.20 parts per million (ppm), and based on the best-fit equation in Figure 2, arsenic concentrations did not fall below 0.20 ppm until harvest distances were greater than ~ 58 km from the stack.

Using Equation (1) to calculate hazard quotients, Figure 3 depicts data for 14 elements in Samples 2010-28 and 2010-59. The elk for Sample 2010-28 was harvested ~19.1 km southeast of the smelter stack, and the elk for Sample 2010-59 was harvested ~101.5 km southwest of the stack. Thirteen elements in Sample 2010-28 exceeded a hazard quotient of 1.0, and elements with the highest $HQ_i$ values were lithium (42.9), manganese (25.6), and arsenic (24.5). In contrast, the only elements in Sample 2010-59 with $HQ_i$ values ≥ 1.0 were

**Table 1.** Sample identification number, sex-age class, animal number (j), distance between harvest location and Anaconda smelter stack ($X_j$), arsenic concentration ($C_j$), arsenic hazard quotient ($HQ_j$), and animal hazard index ($HI_j$) for 56 elk harvested during field campaigns in 2009-2010.

| Sample ID | Class* | j | $X_j$ (km) | Arsenic $C_j$ (ppm) | Arsenic $HQ_j$ | $HI_j$ | Sample ID | Class | j | $X_j$ (km) | Arsenic $C_j$ (ppm) | Arsenic $HQ_j$ | $HI_j$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2009-01 | MA | 1 | 18.3 | 0.83 | 4.2 | 1.9 | 2010-20 | FS | 29 | 93.1 | 0.08 | 0.4 | 0.6 |
| 2009-02 | MS | 2 | 11.7 | 1.11 | 5.6 | 1.4 | 2010-21 | FA | 30 | 93.1 | 0.07 | 0.4 | 0.7 |
| 2009-03 | MS | 3 | 49.5 | 0.69 | 3.5 | 1.7 | 2010-22 | MA | 31 | 59.1 | 0.05 | 0.3 | 0.7 |
| 2009-04 | MA | 4 | 25.0 | 0.81 | 4.1 | 2.0 | 2010-23 | FA | 32 | 85.6 | 0.30 | 1.5 | 0.9 |
| 2009-05 | MS | 5 | 83.4 | 0.27 | 1.4 | 1.3 | 2010-24 | MA | 33 | 83.5 | 0.40 | 2.0 | 0.8 |
| 2009-06 | FS | 6 | 35.3 | 0.70 | 3.5 | 1.2 | 2010-26 | MA | 34 | 51.6 | 0.43 | 2.2 | 1.2 |
| 2009-07 | FS | 7 | 47.0 | 0.29 | 1.5 | 1.2 | 2010-27 | MA | 35 | 51.4 | 0.51 | 2.6 | 5.0 |
| 2009-08 | FA | 8 | 27.9 | 1.06 | 5.3 | 1.0 | 2010-28 | MA | 36 | 19.1 | 4.89 | 24.5 | 10.7 |
| 2009-09 | FS | 9 | 23.8 | 0.29 | 1.5 | 0.8 | 2010-29 | FA | 37 | 19.1 | 0.82 | 4.1 | 1.1 |
| 2009-10 | FA | 10 | 25.0 | 0.43 | 2.2 | 1.1 | 2010-30 | MS | 38 | 25.5 | 0.35 | 1.8 | 1.2 |
| 2009-11 | FA | 11 | 35.1 | 1.16 | 5.8 | 1.3 | 2010-32 | MS | 39 | 45.9 | 0.35 | 1.8 | 1.4 |
| 2010-01 | FS | 12 | 45.9 | 0.06 | 0.3 | 0.7 | 2010-33 | MS | 40 | 45.9 | 0.12 | 0.6 | 1.1 |
| 2010-02 | MA | 13 | 36.5 | 0.44 | 2.2 | 1.2 | 2010-35 | MS41 | 51.6 | 0.09 | 0.5 | 0.6 | |
| 2010-03 | MS | 14 | 85.9 | 0.04 | 0.2 | 0.5 | 2010-36 | FA | 42 | 54.0 | 0.20 | 1.0 | 0.6 |
| 2010-05 | US | 15 | 85.9 | 0.09 | 0.5 | 1.8 | 2010-37 | FA | 43 | 74.8 | 0.15 | 0.8 | 1.7 |
| 2010-06 | MS | 16 | 97.5 | 0.11 | 0.6 | 0.8 | 2010-43 | MA | 44 | 62.2 | 0.14 | 0.7 | 2.0 |
| 2010-07 | FA | 17 | 50.8 | 0.12 | 0.6 | 0.7 | 2010-44 | FA | 45 | 41.1 | 0.22 | 1.1 | 0.7 |
| 2010-09 | FA | 18 | 54.4 | 2.06 | 10.3 | 4.1 | 2010-45 | MS | 46 | 41.1 | 0.19 | 1.0 | 0.7 |
| 2010-10 | FA | 19 | 30.9 | 1.30 | 6.5 | 1.8 | 2010-48 | MA | 47 | 7.5 | 1.98 | 9.9 | 1.7 |
| 2010-11 | MS | 20 | 34.9 | 0.40 | 2.0 | 0.7 | 2010-57 | FS | 48 | 81.0 | 0.07 | 0.4 | 0.6 |
| 2010-12 | FS | 21 | 40.8 | 0.12 | 0.6 | 0.7 | 2010-58 | FA | 49 | 101.5 | 0.04 | 0.2 | 0.5 |
| 2010-13 | MS | 22 | 40.8 | 0.33 | 1.7 | 1.4 | 2010-59 | MA | 50 | 101.5 | 0.07 | 0.4 | 0.5 |
| 2010-14 | MA | 23 | 49.2 | 0.39 | 2.0 | 1.6 | 2010-60 | FS | 51 | 19.1 | 1.33 | 6.7 | 1.1 |
| 2010-15 | MA | 24 | 49.2 | 0.57 | 2.9 | 1.4 | 2010-61 | MS | 52 | 27.4 | 0.82 | 4.1 | 1.8 |
| 2010-16 | FS | 25 | 97.5 | 0.17 | 0.9 | 0.8 | 2010-62 | FA | 53 | 32.1 | 0.26 | 1.3 | 0.6 |
| 2010-17 | FA | 26 | 97.5 | 0.05 | 0.3 | 0.4 | 2010-63 | FS | 54 | 36.5 | 0.20 | 1.0 | 0.7 |
| 2010-18 | MS | 27 | 97.5 | 0.12 | 0.6 | 1.1 | 2010-64 | FA | 55 | 32.1 | 0.09 | 0.5 | 0.5 |
| 2010-19 | FA | 28 | 85.9 | 0.30 | 1.5 | 2.2 | 2010-67 | MA | 56 | 21.4 | 0.50 | 2.5 | 1.1 |

*Class of Animal: MA = Male Adult, MS = Male Sub-Adult, FA = Female Adult, FS = Female Sub-Adult, U = Unknown

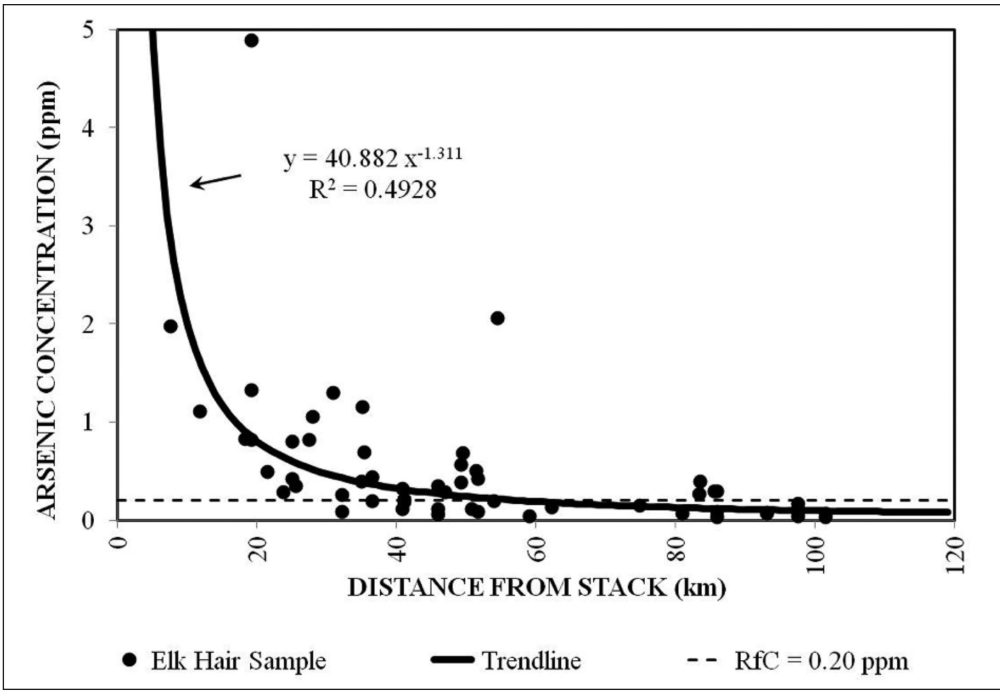


**Figure 2.** Arsenic concentration in hair samples from elk harvested at distances ranging 7.5-101.5 km from the Anaconda smelter stack. A best-fit trendline of the data and an arsenic reference concentration of 0.20 ppm are also shown.

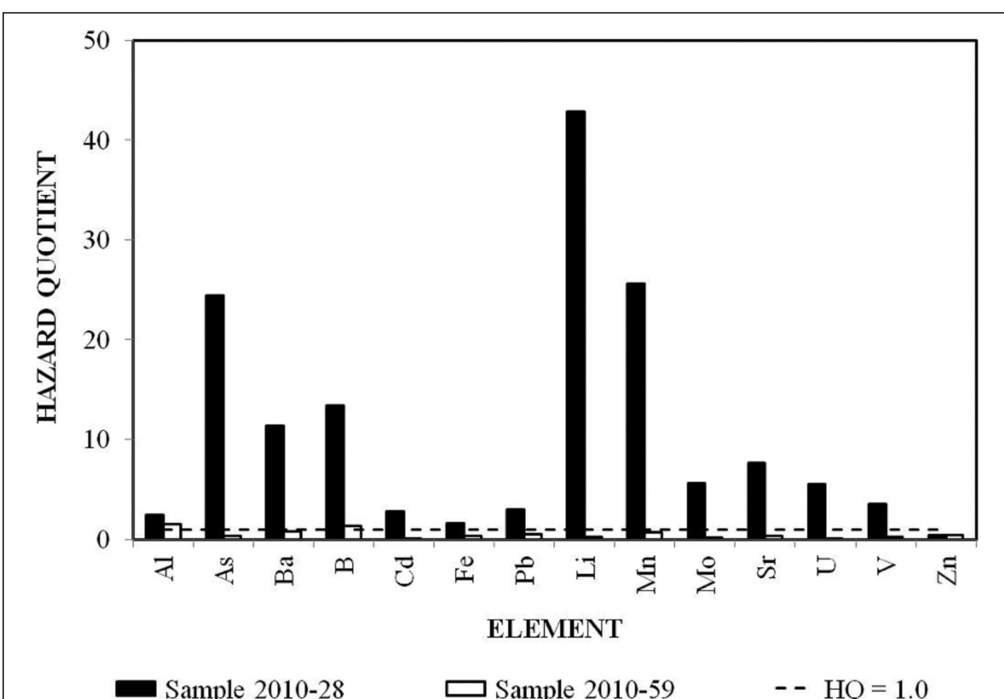


**Figure 3.** Hazard quotient values for Samples 2010-28 and 2010-59. These hair samples were collected from adult elk harvested 19.1 and 101.5 km from the Anaconda smelter stack, respectively. For 14 elements, the corresponding animal hazard indices ($HI_j$) are 10.7 and 0.5.

aluminum (1.5) and boron (1.3). For these two samples, the animal hazard indices from Equation (2) were 10.7 and 0.5, respectively. Based on the $HI_j$ value ≥ 1.0, the elk corresponding to Sample 2010-28 was identified as an animal of concern, as were 32 (~ 57 percent) of the 56 elk sampled (Table 1).

As per concentration statistics of the data set, no samples contained concentrations exceeding the reference concentration for zinc (Table 2), and average and median concentrations were lower than reference concentrations for cadmium, iron, lead, molybdenum, strontium, uranium, vanadium, and zinc. However, because the main source of contamination was the smelter, we divided the samples into four zones according to distance (X) between harvest location and the Anaconda smelter stack: Zone 1 (X<25 km), Zone 2 (26-50 km), Zone 3 (51-75 km), and Zone 4 (76-101.5 km). Element hazard indices were calculated with Equation (3) for each of the four zones (Table 3), and elements of concern were identified.

While Zones 2 and 3 revealed more variability, $HI_i$ values decreased from Zone 1 to Zone 4 for most of the elements. In Zone 1, $HI_i$ was ≥ 1.0 for aluminum, arsenic, barium, boron, lithium, manganese, strontium, and vanadium. Of these elements of concern, the largest hazard indices in Zone 1 were for arsenic (6.5), lithium (6.0), and manganese (5.3). For elk harvested in Zone 4, however, the only elements of concern were aluminum, barium, boron, lithium, and manganese, with manganese exhibiting the largest hazard index (2.8). Zinc showed no spatial variation among the zones, but the element hazard indices were dramatically larger in Zone 1 compared to Zone 4 by factors of 16.7 for uranium, 8.9 for arsenic, 6.7 for cadmium, and 5.6 for lithium.

# Discussion

In this project, we proposed and tested a novel way to study contaminant uptake using elk as biosamplers of environmental conditions near the Anaconda Smelter NPL Site. Even though the Environmental Protection Agency has been directing cleanup activities in the area for many years, large mammal populations have not been addressed. Based on our data, elk in the

**Table 2.** Element (i), reference concentration ($RfC_i$), minimum (Min), maximum (Max), average (Avg), median (Med), and standard deviation (Stdev) concentration ($C_i$) measured in hair samples of 56 elk harvested during field campaigns in 2009-2010.

| I | Element i | $RfC_i$ (ppm) | Min $C_i$ (ppm) | Max $C_i$ (ppm) | Avg $C_i$ (ppm) | Med $C_i$ (ppm) | Stdev $C_i$ (ppm) |
|---|---|---|---|---|---|---|---|
| 1 | Aluminum (Al) | 32 | 5 | 648 | 73 | 49 | 103 |
| 2 | Arsenic (As) | 0.20 | 0.04 | 4.89 | 0.52 | 0.29 | 0.75 |
| 3 | Barium (Ba) | 4 | 1.8 | 45.6 | 6.3 | 4.6 | 6.3 |
| 4 | Boron (B) | 5.9 | 3.6 | 79.1 | 12.2 | 9.9 | 10.1 |
| 5 | Cadmium (Cd) | 0.20 | 0.01 | 0.56 | 0.07 | 0.03 | 0.10 |
| 6 | Iron (Fe) | 99 | 12 | 902 | 84 | 56 | 130 |
| 7 | Lead (Pb) | 2 | 1 | 8 | 1 | 1 | 1 |
| 8 | Lithium (Li) | 0.08 | 0.02 | 3.43 | 0.19 | 0.11 | 0.45 |
| 9 | Manganese (Mn) | 3.3 | 0.97 | 84.51 | 12.90 | 8.54 | 14.13 |
| 10 | Molybdenum (Mo) | 0.22 | 0.02 | 1.6 | 0.14 | 0.08 | 0.26 |
| 11 | Strontium (Sr) | 5.4 | 0.7 | 41.1 | 3.7 | 2.7 | 5.3 |
| 12 | Uranium (U) | 0.20 | 0.005 | 1.1 | 0.07 | 0.015 | 0.16 |
| 13 | Vanadium (V) | 0.60 | 0.02 | 2.47 | 0.35 | 0.14 | 0.52 |
| 14 | Zinc (Zn) | 200 | 70 | 140 | 100 | 100 | 10 |

**Table 3.** Element (i) and element hazard index ($HI_i$) values for Zone 1 ($X_j$<25 km), Zone 2 (26-50 km), Zone 3 (51-75 km), and Zone 4 (76-101.5 km). Also shown is the ratio of the hazard indices for Zone 1:Zone 4.

| i | Element i | Zone 1 $HI_i$ | Zone 2 $HI_i$ | Zone 3 $HI_i$ | Zone 4 $HI_i$ | Zone1:Zone4 Ratio |
|---|---|---|---|---|---|---|
| 1 | Aluminum (Al) | 1.8 | 1.6 | 6.2 | 1.6 | 1.1 |
| 2 | Arsenic (As) | 6.5 | 2.2 | 2.3 | 0.7 | 8.9 |
| 3 | Barium (Ba) | 2.2 | 1.2 | 1.8 | 1.6 | 1.4 |
| 4 | Boron (B) | 3.2 | 2.0 | 1.8 | 1.6 | 2.0 |
| 5 | Cadmium (Cd) | 0.8 | 0.3 | 0.4 | 0.1 | 6.7 |
| 6 | Iron (Fe) | 0.7 | 0.5 | 2.1 | 0.8 | 0.9 |
| 7 | Lead (Pb) | 0.8 | 0.5 | 1.1 | 0.5 | 1.5 |
| 8 | Lithium (Li) | 6.0 | 1.5 | 2.5 | 1.1 | 5.6 |
| 9 | Manganese (Mn) | 5.3 | 3.3 | 5.9 | 2.8 | 1.9 |
| 10 | Molybdenum (Mo) | 1.0 | 0.4 | 1.2 | 0.4 | 2.6 |
| 11 | Strontium (Sr) | 1.3 | 0.6 | 0.6 | 0.6 | 2.3 |
| 12 | Uranium (U) | 0.8 | 0.2 | 0.6 | 0.1 | 16.7 |
| 13 | Vanadium (V) | 1.1 | 0.5 | 0.8 | 0.3 | 3.2 |
| 14 | Zinc (Zn) | 0.5 | 0.5 | 0.5 | 0.5 | 1.0 |

vicinity of the site are still being exposed to significant amounts of contamination. While results from this campaign are site-specific, our technique could be used at other sites where anthropogenic pollution is of concern, and where efficacy of remediation is in question.

Concentrations for many contaminants in our dataset increased for elk harvested closer to the Anaconda stack. Elk are migratory animals, however, and we know that contaminant concentrations in hair are not solely dependent on environmental conditions at the harvest locations. To advance our fundamental understanding of variability within and among the samples, we recommend future research to merge hair sampling with radio-collar tracking for a subset of elk during the growth period of the hair (i.e., for several months prior to hunting season). With subsequent environmental sampling along the migratory path, uptake of contaminants into hair could be correlated to pollution concentrations in the soil, vegetation, and water within a specific habitat. In addition, in-depth medical research should scrutinize health effects associated with uptake of these pollutants by the local elk population. Specifically, studies should address the impact of contaminants on the health of the game animals; however, hunters and their families are also at risk of developing health problems if they routinely ingest wild meat contaminated with arsenic and other contaminants. This latter topic will be the focus of a follow-up paper by our research group.

## Summary

We conducted the first known field campaign using hair samples to investigate uptake of environmental contaminants for harvested wildlife residing in a Superfund area. Based on 56 elk harvested in the vicinity of the Anaconda Smelter NPL Site during hunting seasons in 2009 and 2010, ~57% of the elk sampled were identified as animals of concern. Manganese, arsenic, and lithium were identified as elements of most concern, especially for elk harvested within 25 km of the smelter stack. In addition, hazard indices for uranium, arsenic, cadmium, and lithium were larger for elk harvested within 25 km of the stack by factors of ~17, 9, 7, and 6, respectively, compared to elk harvested within 76-101.5 km.

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The authors thank Ms. Vanna Boccadori and Mr. Braden Burkholder of the Montana Fish, Wildlife and Parks (FWP) for their interest in our project and for letting us obtain samples at the Mill Creek and Divide game stations. We also recognize the hunters who were willing to participate in the campaign. In addition, Mr. John Helfrich is acknowledged for sharing his invaluable knowledge about hunting and trapping. Finally, we are grateful to Dr. David Watts and the laboratory personnel at Trace Elements, Incorporated for agreeing to analyze our somewhat-unconventional samples.

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# Effects of Standard Labor-Wear on Swimming and Treading Water

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## Abstract

We tested the hypothesis that occupational clothing would impair performance during swimming. The sub questions included: (1) Will the standard work wear of a railway worker or laborer impede swimming ability? (2) Will this clothing impact the individual's ability to tread water? We addressed the research questions with three hypotheses. Analysis showed statistically significant p-values and all three null hypotheses were rejected in favor of the three research hypotheses, showing strong evidence that standard labor wear had adverse effects on 11.43 meter/12.5 yard swim time, water treading time and rate of perceived exertion (RPE) during water treading. The mean swim time more than doubled when the subjects wore standard labor-wear and their average rate of perceived exertion increased from 11.6 in standard swim wear to 17.1 in standard labor-wear. It may be beneficial for those workers who work near water to be exposed to educational programs that allow in-water experiences so they develop an understanding of their abilities in, and respect for, the water.

**Key Words**: Labor-Wear, Swimming, Treading, Effects, Swift water Rescue

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## Introduction

In this paper we examine the effect of standard work clothing on people's ability to maneuver in water and rescue themselves from dangerous situations. Several examples demonstrate why understanding clothing effects is important. On May 2nd, 2003, a laborer was working near a pond in Oregon. The pond was surrounded by an angled embankment where the laborer was placing rocks at strategic locations on the inclined bank to prevent erosion. The laborer fell down the embankment and into the pond. By the time that he was rescued from the water, first responders were unable to resuscitate him. It took them 47 minutes to locate and remove the body before resuscitation efforts began (NIOSH, 2003).

In March 2011, a train derailment along the Kootenai River in Northwest Montana required railway workers to be transported to the derailment site via jet boat and to work on an inclined embankment along the river. Each day the workers were transported seven miles down the river. The crew of each boat included a Swift Water Rescue Technician (SRT) as well as the licensed boat pilot.

In July 2011, an oil pipeline on the Yellowstone River ruptured. The ensuing clean-up effort lasted four months and involved over one thousand people. Many of the laborers were transported on jet-boats to islands, and worked in close proximity to the flooding river.

The SRT personnel, who were involved in the jet-boat transportation and safety support of the laborers, conducted rescue training on a daily basis. By predicting how, when and where the workers would enter the water, they could focus training efforts to the most likely situations: a worker falling into the river during transport or during work on the steep embankment along the river. The training was successful. Each and every simulated victim was rescued during the training. But each simulated victim was wearing special equipment designed for the conditions: During the third week in March on the Kootenai River, for example, the air temperature fluctuated between about 30 and 54 degrees Fahrenheit, the Kootenai River was flowing at about 20,000 cubic feet per second, and the temperature of the water was about 39 degrees Fahrenheit (USGS, 2011).

A common question of the laborers during transport was, "If we fall into the drink [while working], how long would we be able to stay up before you guys are able to rescue us?" The average worker being transported to the worksite was wearing standard work-wear: a hard hat with a liner, a heavy Carharrt canvas jacket with insulation under the jacket, Carharrt canvas bib coveralls, and heavy leather work-boots with steel toe protection.

The Occupational Safety and Health Administration requires the use of personal protective equipment and personal flotation devices (PFD) when individuals are working on, over or near water when a drowning hazard exists (U.S. Department of Labor; 1926.106(a)). However, workers don't always comply with this requirement The purpose of this research was to determine how swimming performance, water treading time and perceived exertion are influenced when workers are wearing typical labor-wear compared to swim-wear. All study procedures were reviewed and approved by an independent investigational review board. The main research question was, what effects would standard labor-wear have on swimming ability and ability to self-rescue? The sub questions that guided the development of our hypotheses were:

Will the standard labor-wear impede swimming ability?

Will this clothing impact the individual's ability to tread water?

## Hypotheses:

***Null Hypothesis 1:***

The average 11.43 meter/12.5 yard swim time in standard labor-wear is ≤ the average 12.5 yard swim time in standard swim-wear.

***Research Hypothesis 1:***

The average 11.43 meter/12.5 yard swim time in standard labor-wear is > the average 12.5 yard swim time in standard swim-wear.

***Null Hypothesis 2:***

The average time to failure when treading water in standard labor-wear is ≥ the average time to failure when treading water in standard swim-wear.

***Research Hypothesis 2:***

The average time to failure when treading water in standard labor-wear is < the average time to failure when treading water in standard swim-wear.

***Null Hypothesis 3:***

The average rate of perceived exertion (RPE) when treading water in standard labor-wear is ≤ the average RPE when treading water in standard swim-wear.

***Research Hypothesis 3:***

The average RPE when treading water in standard labor-wear is > the average RPE when treading water in standard swim-wear.

## Methods

We tested the hypotheses in a controlled indoor pool environment. The subjects participated in four trials:

- *Trial 1:* Timed freestyle swim of 11.43 meter/12.5 yards in standard swimwear.
- *Trial 2:* Timed freestyle swim of 11.43 meter/12.5 yards in standard labor-wear.
- *Trial 3:* Timed water tread in standard swimwear.
- *Trial 4:* Timed water tread in standard labor-wear.

Nine volunteer subjects were chosen based on current or previous experience and credentials. The inclusion criteria was set so only those who have swiftwater rescue technician (SRT) certification, lifeguard certification, and/or competitive swimming experience were considered. The SRT has demonstrated swimming abilities that meet the Whitewater Rescue Institute's (WRI) minimum standards to self-rescue and to rescue victims of swiftwater accidents, and certified lifeguards are required to pass a swim test to demonstrate proficiency.

The exclusion criteria included any current student of the researcher's and was guided by the American College of Sports Medicine risk stratification process. American College of Sports Medicine (ACSM) guidelines suggest a pre-participation screening that identifies current medical conditions that would exclude those who are at risk for adverse cardiovascular, pulmonary, metabolic, as well as other conditions, that would cause adverse responses to exercise (ACSM, 2009). The list of conditions that excluded a subject included:

- Pregnancy
- Diabetes
- Hypertension or are taking blood pressure medication
- Asthma
- Concerns about safety of exercise or swimming ability
- Heart surgery
- Chest discomfort with exercise
- Unreasonable breathlessness with exercise
- Unexplained dizziness or fainting
- Musculoskeletal problems that limit functional capacity
- Current smoker

All subjects completed the pre-participation screening to identify anyone who should be eliminated. Additionally, all subjects were under the age of 50 years.

Safety of the subjects for the 11.43 meter/12.5 yard swim was ensured in two ways. First, the 11.43 meter/12.5 yard swim was conducted in water that is 4 feet deep, in which all of the subjects were able to stand. The subjects were instructed to simply stand up if they were in distress. The subjects were also surrounded by lifeguards in the water and on the deck with appropriate rescue equipment as back-up measures.

Safety for the subjects during the treading consisted of three lifeguards/SRTs monitoring the subject with rescue flotation devices. Using Borg's Rate of Perceived Exertion (RPE) Scale, the subjects were required to verbally communicate their exertion level on a scale of 6 to 20. When the subject neared the extreme end of the scale and their efforts could no longer continue, they were instructed to reach for the gutter to self-rescue. If they were unable to self-rescue the rescuers planned to use the rescue/flotation equipment to assist the subject.

Prior to the trials, each subject was given the following instructions regarding the use of the RPE Scale to ensure safety:

"While performing the treading, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the treading feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion. Look at the rating scale below while you are treading; it ranges from 6 to 20, where 6 means 'no exertion at all' and 20 means 'maximal exertion'. Choose the number from below that best describes your level of exertion. This will give us a good idea of your intensity level and how much longer the treading will continue." The RPE scale with related descriptions includes (Borg, 1998, pg. 47):

| | |
|---|---|
| **6** ....... | No exertion at all |
| **7** ....... | Extremely light |
| **8** | |
| **9** ....... | Very light - (easy, comfortable pace) |
| **10** | |
| **11** ....... | Light |
| **12** | |
| **13** ....... | Somewhat hard (It is quite an effort; you feel tired but can continue) |
| **14** | |
| **15** ....... | Hard (heavy) |
| **16** | |
| **17** ....... | Very hard (very strenuous, and you are very fatigued) |
| **18** | |
| **19** ....... | Extremely hard (you cannot continue for long at this pace) |
| **20** ....... | Maximal exertion |

The subjects were all read an informed consent form that emphasized the voluntary nature of this study, and that if they were uncomfortable doing anything in the study assessment they had the option to not participate. The decision to take part in this research study was entirely voluntary, and subject withdrawal from the study could have occurred at any time.

## Procedures

The subjects were read the informed consent form, and were instructed on the proper use of Borg's (RPE) scale. Resting heart rate and blood pressure were measured at this time. The subjects were informed that the RPE scale were to help the rescuers by providing them information that will prepare them to assist the subject. The order of the timed trials included:

- First all subjects swam the 11.43 meter/12.5 yard swim in standard swim-wear
- 15-minute rest
- All subjects swam the 11.43 meter/12.5 yard swim in standard labor-wear
- 15 minute rest
- Water treading test in standard swim-wear
- One week rest
- Water treading test in standard labor-wear

## Results

Table 1 shows the complete results of the trials. The mean 11.43 meter/12.5 yard swim time for subjects in standard swim-wear (Sw) was 10.05 seconds and the mean swim time for subjects in standard labor-wear (Sw L) was 23.37 seconds. The Wilcoxon Signed Rank test is appropriate for relatively small sample sizes, and showed a p-value of 0.0039. Based on this result we reject null hypothesis 1 in favor of research hypothesis 1 at a significance level of 0.05. Table 2 shows the statistical results for the 12.5 yard swim.

The mean treading time for subjects in standard swim-wear (Tr) was 12.99 minutes while the mean treading time for subjects in standard labor-wear (Tr L) was 8.41 minutes. The Wilcoxon Signed Rank test showed a p-value of .0156. Based on this result we reject null hypothesis 2 in favor of research hypothesis 2 at a significance level of 0.05. Table 3 shows the statistical results for the water treading tests.

The mean RPE for subjects treading in standard-swim wear (RPE Tr) was 11.67 seconds, and the mean RPE for subjects treading in standard labor-wear was 17.11 seconds. The Wilcoxon Signed Rank test showed a p-value of 0.0156 . Based on this result we reject null hypothesis 3 in favor of research hypothesis 3 at a significance level of 0.05. Table 4 shows the statistical results for the subjects' RPE for the water treading.

The limitations to the study include the non-randomized order of trials which could have caused an order effect. We did this because we felt it would be the safest way to conduct the trials but acknowledge that it could have an effect either way on the results. Additionally, a small sample size and the lack of objective fitness data, body composition in particular, for each subject, would have allowed us to discuss the possible effects of differences in body composition on the treading results. The subjects were very fit and may not be the best representatives of the average work-force representative; again pre-test fitness measurements may have allowed us to compare the subjects with average fitness levels in the American work-force. We established and adhered to the subject guidelines for safety purposes because we did not want any of the subjects to be traumatized by the experience. That is, we had all subjects begin each trial with swim-wear to prepare them for the more difficult labor-wear trial. Each subject was allowed to rest for at least 15 minutes, and heart rates were monitored prior to the labor-wear trials to ensure the subject was in a resting state. We acknowledge, however, that the non-randomized order in which this was conducted may have had an order-effect.

Also, the labor-wear only consisted of boots and the coveralls; no inner layers were worn. Insulation layers may have

**Table 1.** Results

| Subject | Age | RHR | Sw | Sw L | Tr | Tr L | RPE | RPE L |
|---|---|---|---|---|---|---|---|---|
| **1** | 46 | 60 | 8.29 | 18.5 | 15:00 | 10:54 | 15 | 20 |
| **2** | 21 | 66 | 8.61 | 23.9 | 10:50 | 1:06 | 20 | 20 |
| **3** | 21 | 60 | 10.34 | 15.3 | 5:25 | 55.07 | 20 | 20 |
| **4** | 22 | 78 | 11.68 | 33.03 | 10:40 | 56 | 20 | 20 |
| **5** | 23 | 78 | 10.24 | 30.3 | 15:00 | 8:35 | 6 | 20 |
| **6** | 21 | 72 | 9.46 | 20.9 | 15:00 | 15:00 | 6 | 8 |
| **7** | 20 | 78 | 8.54 | 17 | 15:00 | 8:18 | 6 | 20 |
| **8** | 22 | 84 | 11 | 23 | 15:00 | 15:00 | 6 | 14 |
| **9** | 21 | 95 | 12.33 | 28.44 | 15:00 | 15:00 | 6 | 12 |

**Table 2.** Means 11.43 meter/12.5 Yard Swim

| | N | Mean | St. Dev. | Min. | Max. | Range | *p*-value |
|---|---|---|---|---|---|---|---|
| **Sw** | 9 | 10.05 | 1.44 | 8.29 | 12.33 | 4.04 | |
| **Sw L** | 9 | 23.37 | 6.15 | 15.3 | 33.03 | 17.73 | 0.0039 |

**Table 3.** Means Treading

| | N | Mean | St. Dev. | Min. | Max. | Range | *p*-value |
|---|---|---|---|---|---|---|---|
| **Tr** | 9 | 12.99 | 3.38 | 5.42 | 15 | 9.58 | |
| **Tr L** | 9 | 8.41 | 6.14 | 0.92 | 15 | 14.08 | 0.0156 |

**Table 4.** Means RPE

| | N | Mean | St. Dev. | Min. | Max. | Range | *p*-value |
|---|---|---|---|---|---|---|---|
| **RPE Tr** | 9 | 11.67 | 6.89 | 6 | 20 | 14 | |
| **TRPE Tr L** | 9 | 17.11 | 4.59 | 8 | 20 | 12 | 0.0156 |

had a further impact on the measurements. The environment was controlled; the water was warm, clear and non-moving when, in reality, many water incidents occur in cold, dark moving water.

## Discussion

Based on the results described above, we can say with confidence that it is more difficult to tread water and swim 12.5 yards in coveralls and heavy work boots when compared to wearing a swim-suit. An individual who ends up in the water with standard labor-wear should expect the physical requirements needed for self-rescue to be much more difficult than if they had simply fallen into a swimming pool with their swim suit on. Three of the subjects who were able to tread water for more than 5-10 minutes in their swim trunks were only able to tread water for around one minute in the labor-wear. All nine subjects showed slower swim times with labor-wear. One subject only required an extra 5 seconds, but the other 8 subjects all required double or triple their swim-wear times.

All of the subjects were current or former athletes. Two were college football players, two were college basketball players, and one was a college volleyball player. Though standard fitness assessments were not part of the protocol, the subjects were given an initial swim test as part of the institutional review board procedure agreement, and they all appeared to have a high level of physical fitness. We believe the effects on swimming and treading efficiency would be much more pronounced on physically unfit individuals.

All of the subjects reported higher levels of difficulty when swimming or treading in the labor-wear, but there was disagreement on whether the treading with the labor-wear or swimming with the labor-wear was harder. Out of the nine subjects, all four of the men believed that the treading was more difficult than the swimming, and all five women believed that the swimming was more difficult than the treading.

The distance of 11.43 meters/12.5 yards is a short swim; five of the nine subjects stated that the swim was much more difficult than the treading. For them, self-rescue of distances greater than this may not be possible. Additionally, the controlled environment and relatively warm water is not universally applicable. Self-rescue in cold, dark, moving water is different, and probably more difficult, than self-rescue in a warm pool with non-moving, clear water.

The original question can now be answered: In some cases complete exhaustion occurs in less than one minute. This is one reason the Occupational Safety and Health Administration requires a life-vest when workers are near a drowning hazard. Simply wearing a life-vest, a personal flotation device (PFD), will prolong this time; however this rule is not always followed and wearing a PFD will not always prevent the loss of a life.

Based on the results of this study we believe it may be beneficial for those who work near water to participate in educational programs that allow in-water experiences so they develop an understanding of their abilities in, and respect for, the water. We also recommend that any company requiring their employees to be working on or near water to consider implementing water safety plans that may include swift water rescue professionals to conduct training and to be on-site to help prevent water injury and death.

## Recommendations for Future Research

To gather more information, conducting fitness assessments on each subject would be beneficial. Also, adding the insulation layers that are normally worn may more accurately reflect a laborer's physiological response in the water. Though it may be difficult to receive institutional review board approval, conducting this research in moving water, such as an actual river would be more realistic. The addition of a PFD would also have an effect on self-rescue; treading would not be as difficult if a PFD is worn. Self-rescue swimming with a PFD should be addressed as well; wearing a PFD doesn't always mean self-rescue is guaranteed. Monitoring heart rates and comparing different strokes would provide information about which strokes would be more efficient in standard labor-wear.

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# Biological Sciences – Terrestrial

## Abstracts

### Montana Chapter of the Wildlife Society 50th Annual Meeting

***50 Years of Partnerships:***
***What have we learned and where are we headed***

**February 28 - March 2, 2012**

**Great Falls, Montana**

## General Abstracts

**Alphabetical By First Author's Last Name**
**(* Denotes Presenter)**

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## Incorporating Ecohydrologic Variables Into Modeling Of Patterns Of Montane-Mammal Distribution And Abundance

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Montane ecosystems have been suggested by both paleontological and contemporary research to often be systems of relatively rapid faunal change, compared to many valley-bottom counterparts. In addition to often (but not always) 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. We present new results of ecoregional-level analyses of American pikas (*Ochotona princeps Richardson*) that illustrate how biologically relevant derived hydrological variables can be important to predictors of abundance. We also present new results from the Northern Rocky Mountains that illustrate how behavioral plasticity can, in at least some cases, 'soften' the boundaries of species' bioclimatic niches. Landscape Conservation Cooperatives and Climate Science Centers are newly emerging efforts that may contribute greatly to broad-scale, mechanism-based investigations to inform management and conservation of diverse montane wildlife and the ecosystem components with which they interact. Based on our empirical findings and our review of the literature, we propose tenets that may serves as foundational starting points for our expanding research on montane animals acrsoss the Northern Rocky Mountain Region.

## Modeling Carnivore Sign Data: A Case Study With The Carnivore Guild In A Ranch In Eastrn Montana

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Track deposition patterns by carnivores on a 54 $km^2$ ranch in eastern Montana were recorded with a sand strip passive index survey method over the course of 33 days. Carnivore tracks identified included coyotes ($n$ = 17), bobcats ($n$ = 8), feral cats ($n$ = 6), pumas ($n$ = 1), and long-tailed weasels ($n$ = 1). Using temporal, weather, and habitat covariates, coyote intrusions were modeled with generalized linear models using a negative binomial distribution and log link. An information theoretic approach using the Akaike information criterion adjusted for sample size (AICc) to compare the relative support of multiple models indicated that habitat type had a strong influence on coyote track deposition, and that weather and temporal covariates were comparatively poor descriptors of coyote track patterns. Autocorrelation functions revealed no evidence for daily temporal autocorrelation of coyote intrusion numbers in either habitat, and a Spearman's rank correlation coefficient suggested little between-habitat daily intrusion correlation ($r$ = -0.21). Use of open areas by coyotes has been well documented in the literature, and the data analyzed in this report are in agreement with said studies.

## Bio-Energetic Value of The Flathead and Smith Valleys in Northwest Montana for Spring Waterfowl Migration

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Chris Hammond, Wildlife Biologist, Montana Fish, Wildlife & Parks.

The abundance of lakes, rivers, streams, wetlands, and agricultural lands of the Flathead and Smith Valleys in northwest Montana attracts a significant number of migratory waterfowl moving from wintering grounds to breeding habitats each spring. These diverse habitats provide food and resting areas for thousands of waterfowl and other waterbirds each year. These valleys are also undergoing rapid habitat transformation due to growth in human population with concomitant conversions from rural agricultural and riparian habitats to more residential and commercial development. To quantify the current extent, distribution, importance, and species that use this area as a spring stopover, we initiated a randomly stratified, weekly, simultaneous waterfowl survey of selected areas from early March through April. We began in spring 2010 and will continue through spring 2012. The data will be extrapolated to the entire study area and for the 2-month period to develop an estimate of total annual waterfowl feeding days by species. Habitat data are also being incorporated. Preliminary results from first 2 years of data indicate that the 4 most common migrant waterfowl species, in order of total numbers counted, are Mallard, Northern Pintail, Canada Goose, and American Wigeon. Preliminary extrapolations of waterfowl survey data in terms of bioenergetics will be summarized.

# Using Remote Camera Technology To Survey Sharp-Tailed Grouse Leks In Montana

Diane Boyd*, Gary Olson, Nathan P. Birkeland, and Derek Reich

Some of the biggest challenges in conducting lek surveys for sharp-tailed grouse in Montana are weather-related road access, distance between leks, visibility, and determining the maximum number of males and females at the lek. The optimum time to survey peak dancing displays on leks is during the first few hours of morning daylight in April. Surveys are traditionally conducted by biologists with binoculars or scopes in vehicles racing between distant leks to count sharptails before the dancing stops for the day. Vehicular access to private land, snowstorms, muddy roads, and difficult hiking create problems in reaching leks during the peak mating season, and thus limit the efficacy and scope of sharp-tailed grouse surveys. Biologists have used aircraft to locate new sharp-tailed grouse leks but this method is costly and not commonly employed. The authors found no reports of remote cameras being used to count sharp-tailed grouse on leks. The objective of this study was to determine if remote cameras would be an accurate and cost-effective tool to survey sharp-tailed grouse leks. The resulting camera images recorded more birds at a lek than ocular estimates or flushing counts yielded. Additionally, the cameras worked well in all types of weather conditions, were low maintenance, reduced human disturbance to leks, and were cost-effective. Incidental data collected included visitation to leks by predators, length of lek abandonment post-disturbance, and effects of weather conditions on dancing.

# Moose Management In Southwest Montana: Insights From Four Years Of Field Research

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From 2007-2010, Montana Fish, Wildlife and Parks conducted research on moose ecology on the Mount Haggin Wildlife Management Area in southwestern Montana. In this presentation, we will briefly review our methodology and results, but will largely focus on the management implications of this research and potential ideas for future research. The goals of this research were to determine the habitat selection of cow moose during winter with an emphasis on willow community importance and to examine population-scale willow browse utilization through browse patterns. We also sought to contribute to a foundation for future research on moose in Montana. Using browse surveys on willow (Salix spp.) and GPS collars on cow moose, we were able to determine the current intensity of willow browse and basic habitat use of cow moose (e.g. home range size and location), and to model variables associated with both browse utilization and habitat selection. Management implications of the browse surveys include suggestions regarding sample sizes and sample site placement for future monitoring of willow community health or browse utilization. Additionally, species preference by moose has implications for riparian restoration. The habitat selection analysis showed the importance of willow and conifer communities and has implications for habitat conservation and aerial survey methods. Future research on moose ecology in Montana should focus on the impact of changing habitat and climate on habitat selection and population dynamics, the role of predation on populations of moose, and improving aerial or other survey techniques to more accurately monitor moose population trends.

# Climatic Variation And Age Ratios In Bighorn Sheep And Mountain Goats In The Greater Yellowstone Area

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Using management data regularly collected by state and federal agencies, we indexed recruitment rates of bighorn sheep and mountain goats in the Greater Yellowstone Area (GYA) by calculating young:adult ratios. Annual and long term regional climatic conditions were indexed using data from Natural Resource Conservation Service Snotel sensors across the GYA. Linear regression models were used to assess hypotheses that recruitment rates in bighorn sheep and mountain goats in the GYA were associated with annual and regional variation in climatic conditions. The initial dataset consisted of 685 bighorn sheep lamb:ewe ratios from 21 herds since 1960 and 184 mountain goat kid:adult ratios from 18 herds since 1966. After censoring data, 369 bighorn sheep records remained, which were split into three seasonal subsets, and 123 mountain goat records remained in a single dataset. Findings suggest that recruitment rates in bighorn sheep and mountain goats were associated with annual variation in both pre-birth and post-birth climatic conditions, interacting with long term regional climate conditions. Additionally, strong interactions were found between precipitation during the birthing season and winter severity. Collectively, these findings suggest that recruitment in bighorn sheep and mountain goat populations in the GYA may be sensitive to changes in future climate conditions and that the response may vary regionally across the GYA.

# Evaluating Bottom-Up And Top-Down Effects On Elk Survival And Recruitment: A Case Study In The Bitterroot Valley

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Understanding the contribution of recruitment rates to overall growth rate in ungulate populations is a fundamental challenge in wildlife management. Ungulate populations with low recruitment rates may result in population level declines over time. In the southern Bitterroot Valley of western Montana, the decline of elk (*Cervus elaphus*) populations and calf recruitment occurred concurrently with wolf (*Canis lupus*) recovery. However, a multitude of abiotic, bottom-up and top-down factors likely affect recruitment rates and the relative affects of these factors on elk calf survival rate likely vary temporally throughout the first year. We studied cause-specific mortality of elk calves to understand the role of competing mortality risk on calf recruitment in the East Fork and West Fork of the Bitterroot Valley, Montana. A total of 66 neonatal elk calves were captured in spring 2011 and an additional 31 6-month

olds in late November 2011. We will analyze survival using a Weibull parametric survival model, and cause-specific mortality using a competing risks framework. Preliminary analyses suggest the potential for competing risks between black bears, mountain lions, and wolves. As the study progresses into the second year, we will evaluate the role of summer range nutritional resources on maternal condition, lactation performance, and calf birth weights and survival. Our study will fill a gap regarding the role of summer vs winter mortality in elk and the role of nutrition in first year survival. The study will complement previous studies on elk population dynamics and inform elk population management following carnivore recovery.

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## Moving Wildlife Under US Highway 93 in Montana's Bitterroot Valley Through Wildlife Crossing Structures

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The impediment that the Bitterroot Valley's roads and vehicle traffic pose for wildlife movement can be partially mitigated with wildlife crossing structures. This study evaluates 18 wildlife crossing structures installed by Montana Department of Transportation along US Highway 93, south of Missoula. Through the use of camera traps, this ongoing study evaluates the efficacy of these crossing in allowing wildlife to move safely under the road, and in reducing wildlife-vehicle collisions between the communities of Lolo and Hamilton. Photographic data on white-tailed deer use were analyzed for success rate and rate of repellence. Use of structures by other species of wildlife was also analyzed. In three years of post-construction monitoring, success rates ranged from zero to two white tailed-deer passes per day. Carnivores were photographed using crossings and moving over the highway at grade. At this time, bridge structures have a higher success at passing white-tail deer that approach them than culverts, except for a large (6 m wide and high) steel culvert, which worked as well as bridges. Fencing to crossings is important: bridges without wildlife fencing had success rates well under 0.2 deer passes per day. At this time overall trends appear to suggest that: wildlife fencing, more vegetation at the ends of structures, and wider structures result in higher success rates for white-tailed deer. When the study is completed in 2015 we will have a better understanding of the structure and landscape variables important to facilitate wildlife use of wildlife crossing structures.

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## Timing Of Cattle Graze As A Management Tool For Plant And Invertebrate Communities In The Centnenial Valley, Montnana

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Kyle Cutting, US Fish and Wildlife Service, Red Rock Lakes NWR, Lima, Montana 59739

Grazing is an important natural disturbance in the western US. While many studies have focused on the effects of grazing intensity and frequency, little is known about the importance of graze timing and how it can affect plant and invertebrate community structure and productivity. Timing may be a critical factor for promoting ecological heterogeneity,

biological diversity, and abundance of food resources for native birds. Our primary goal is to understand how timing of graze and climate variability interact to influence plant and invertebrate communities throughout the growing season in wet meadows and grasslands in the Centennial Valley of southwest Montana. In 2011, control (no graze), early graze (beginning June 15), and traditional late graze (beginning July 15) treatments were established and replicated in a heterogeneous, irrigated, wet meadow habitat. From June-September, plant and invertebrate communities were quantitatively sampled to examine dynamics of biomass and diversity. In 2012, a similar experimental design will be implemented in a less-disturbed and drier native grassland. A new component will examine interactions between climate variability and timing by incorporating a water-addition treatment to simulate the extra moisture resulting from a wet year. We predict that increased climate variability will likely impact wet meadow and grassland habitat plant and insect phenology, with timing of graze becoming particularly critical during dry years. We will discuss results from 2011 and where we plan to go in 2012 with the water-addition treatment.

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## Spatial Search And Efficiency Rates As Components Of Wolf Predation Risk

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Anthropogenic linear features are hypothesized to increase wolf (*Canis lupus*) predation risk for a threatened ungulate, woodland caribou (Rangifer tarandus caribou). Previous research has shown that these features are selected by wolves while searching for prey, but their effect on the net efficiency of predation, measured in kills per day, has not been addressed. We use resource selection and proportional hazards modeling to assess the spatial drivers of both search and efficiency rates of wolf predation in a multi-prey system. Topographic variation consistently affected wolf search rates and the predation efficiency of wolves while searching. However, the effects of anthropogenic footprint upon the total predation risk imposed by wolves were mediated solely by changes to wolf search rate; wolf predation efficiency generally did not change with proximity to anthropogenic linear features as previously hypothesized. Predicted models of the cumulative hazard encountered by wolves validated well with among-pack variation in kill rates, suggesting that spatial hazard models allow the scaling up of local heterogeneity to population-level dynamics. Lastly, we estimated an integrated spatial model of relative predation risk as the product of both search and efficiency rates, which captured the distinct contributions of spatial heterogeneity to each component of risk.

# Initiating GPS & VHF Telemetry Studies On Mountain Ungulates In The Greater Yellowstone Area

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Telemetry studies on bighorn sheep (*Ovis canadensis*) and mountain goats (*Oreamnos americanus*) in the greater Yellowstone area (GYA) are relatively rare, especially in comparison to other large mammals. There is therefore a significant dearth of detailed information on mountain ungulate demographic and spatial ecology as well as competition dynamics between the non-native mountain goat and the native bighorn sheep. The Mountain Ungulate Research Initiative is seeking to gain this valuable management and conservation information by initiating GPS and VHF radio telemetry studies across the GYA. We have selected ten study sites that represent the varying ecological settings of this ecosystem with differences in climate, geology, herd size, disease history, land use and management, migratory and non-migratory herds, sympatric and allopatric herds, and high and low elevation ranges. In addition, we have developed a dual collar, multiple deployment strategy to efficiently maximize collection of ecological data and support long-term research goals. This includes the deployment of a GPS collar simultaneously with a VHF collar for each animal instrumented. After two years of fine spatial- and temporal-scale data collection the GPS collars will release for recovery while the VHF collars will remain on animals to obtain an additional five years of demographic data. The recovered GPS collars will then be refurbished and redeployed with new VHF collars on additional animals. The presentation will describe these telemetry studies and strategies, as well as report on the progress of current and planned telemetry study efforts.

# Geo-Statistical Methods For Detecting Elk Parturition Sites From Gps Collar Data

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There is an increasing awareness of the importance of juvenile survival in ungulate population dynamics, and the accurate prediction of parturition habitat may allow for more effective management. Detecting birth sites in a statistically rigorous way, however, often requires intensive field efforts that may not be possible for all studies. We developed a hierarchical two-stage clustering analysis for identifying elk parturition locations, which can

be conducted retrospectively using only GPS location data. We validated our approach using a dataset of 59 adult female elk (*Cervus elaphus*) fitted with both a Global Positioning System (GPS) collar (30-minute sampling interval) and vaginal implant transmitter (VIT) For the top parameter set, approximately 80% of estimable parturition sites were within 1 km of their respective VIT location. Roughly 10 % of our predicted birthing locations were over 2 km away from the VIT location, but many of these events could be filtered from the analyses due to their clustering attributes. Designed to minimize Type II errors this filtering also removes a subset of birthing sites that close to VIT locations, and magnitude of this effect varied across parameter sets. Sub-sampling of the GPS dataset from 30 min to 1, 2, 3, and 6 hour intervals resulted in modest reductions in the efficacy of our approach. With the use of GPS collars in ungulate studies on the rise, our approach provides managers with additional information on birth site locations at no additional cost over and above a typical GPS study.

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## Analyzing Climate Data For Wildlife Studies

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Climate is one of the driving forces affecting wildlife and fisheries. Access to daily data from SNOTEL stations in the mountains and Climatological stations in the valleys provides data on temperature, precipitation and snow that can be interpreted to help understand response to climate variables. Dates of spring and fall green-up, growing degree-days and forage production can be derived. Snow water equivalent (SWE) can be estimated from Climatological stations. Start of snow accumulation, maximum accumulation and date of maximum SWE, and date of melt-out can be determined for each station. Critical temperatures are different for each species and accumulated effect of cold temperatures can be determined from daily minimum temperatures. Long-term trends and annual variations can help explain fluctuation in population, reproduction, predation and mortality. Relationships have been developed relating plant phenology to climatic variables for lilacs (which have been used as a surrogate for estimating growing seasons) and Whitebark Pine. SWE can be related to migration and predation

Keetch Byram Drought Index (KBDI) was developed for fire spread analysis but can also be used as an index to soil moisture. Index of Winter Severity (IWS) can be calculated for various areas and species using a combination of SWE, forage production and critical temperatures. Streamflows can be related to SWE, soil moisture, spring precipitation and temperatures.

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## Population Trends Of Bighorn Sheep And Mountain Goats In The Greater Yellowstone Area

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Bighorn sheep (Ovis canadensis) and mountain goats (*Oreamnos americanus*) are important components of the large mammal community in the Greater Yellowstone Area (GYA) and are of considerable public interest. However, foundational ecological research concerning these species is limited. We analyzed historic bighorn sheep and mountain goat population counts collected by management biologists using ln-linear regression to estimate herd growth rates (λ). The analyzed dataset consisted of 538 bighorn sheep counts since

1971 and 120 mountain goat counts since 1966. Most mountain goat count units experienced a positive growth rate and increased their distributions over recent decades. Bighorn sheep growth rates were more variable among the 26 recognized herd units in the GYA. We used the historic count data to evaluate the hypothesis that sympatry of non-native mountain goats with bighorn sheep adversely affected bighorn sheep populations. This was accomplished by comparing the growth rates of sympatric herds with that of allopatric herds. There was no evidence that sympatric herd growth rates were significantly lower than allopatric herd growth rates. We caution, however, that many counts in consecutive years suggested larger changes in abundance than what would be reasonable to expect from biological processes. We suspect that variability in counts likely reflects varying detection probability and the overall difficulty of counting mountain ungulates. Therefore, conclusions derived from these data should be further evaluated with more detailed demographic studies in the future.

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# Inter-Individual Isolation By Distance: Implications For Landscape Genetics

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Many approaches to understanding the influence of landscape on gene flow account for isolation by distance, a phenomena where individuals that are closer together are more likely to be more closely related. Most theoretical research has focused on isolation by distance between populations. We simulated the expected isolation by distance patterns between individuals within a finite population and found an asymptotic pattern. New null models are needed in landscape genetic approaches to correctly account for isolation by distance patterns. We will briefly review isolation by distance and discuss the factors (time, variance in dispersal, and mutation rates) influencing isolation by distance patterns. Our results have implications for estimating how difficult it is for animals to move through the landscape.

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# The Effects Of Special Mule Deer Buck Regulations On Mule Deer Populations And Harvest

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We evaluated the effects of 3 restrictive season types on mule deer population and harvest characteristics in 41 Montana hunting districts (HDs). Using a mixed-effects, before-after-control-impact modeling framework, we analyzed 6 harvest and hunter use response variables, and 4 population response variables. Buck:doe ratios increased by 0.42 bucks:100 does and 0.33 bucks :100 does per year, following changes to a shortened season and limited permits, respectively. We found no significant change in buck:doe ratios in unlimited permit HDs. All restrictive season types resulted in declines in hunter numbers and days. HDs with no restrictions, with limited permits and with unlimited permits also showed a downward annual trend in hunter numbers. In shortened season HDs, a significant loss in hunter

numbers was followed by a slow return of hunters back to those HDs. Limited permit HDs had a statistically greater proportion of bucks with ≥4 points on at least one antler, a lower number of bucks harvested annually, and a smaller total number of ≥4 point bucks harvested than in HDs with no buck restrictions. For those same 3 response variables, unlimited and shortened season HDs were not different than HDs without restrictions. In all three restricted regulation HDs there was an annual increase in the observed spring fawn:adult ratios even though the general trend was for a decreasing fawn:adult ratio of 0.83 fawns:100 adults per year in HDs with no restrictions.

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# Predicting Prey Population Dynamics From Kill Rate, Predation Rate And Predator-Prey Ratios In Three Wolf-Ungulate Systems

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Predation rate (PR), kill rate and predator-prey ratio's are all thought to be fundamental statistics for understanding and managing predation. However, relatively little is known about how these statistics explain prey population dynamics. We assess these relationships across three systems where wolf–prey dynamics have been observed for 41 years (Isle Royale), 19 years (Banff) and 12 years (Yellowstone). Theoretical simulations indicate that kill rate can be related to PR in a variety of diverse ways that depend on the nature of predator–prey dynamics. These simulations also suggested that the ratio of predator to-prey is a good predictor of prey growth rate. The empirical relationships indicate that PR is not well predicted by kill rate, but is better predicted by the ratio of predator-to-prey. Kill rate is also a poor predictor of prey growth rate. However, PR and predator-prey ratio's each explained significant portions of variation in prey growth rate for two of the three study sites. Our analyses offer two general insights. First, it remains difficult to judge whether to be more impressed by the similarities or differences among these 3 study areas. Second, our work suggests that kill rate and PR are similarly important for understanding why predation is such a complex process. We conclude with a review of potential management applications of predator-prey ratio's and the assumptions required to understanding prey population dynamics.

## Bat Activity In Riverine Stands Of Native Plains Cottonwood And Naturalized Russian Olive In Southeastern Montana

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Replacement of native riverine gallery forests by woody exotics is a significant conservation issue throughout the western United States. Controversy surrounds the management of Russian olive (*Elaeagnus angustifolia*), a small Eurasian tree now naturalized in the west, because its detrimental effects to native vegetation are offset to some degree by resources (food and cover) it provides for some wildlife species. We examined the relative use by bats of plains cottonwood (*Populus deltoides*) and Russian olive by measuring bat activity with electronic bat detectors in stands dominated by each plant species (cottonwood: 12, Russian olive: 6) along the Yellowstone and Powder rivers in eastern Montana. Bats were detected in all stands, but activity was greatest in those dominated by cottonwood. Bat activity was also positively correlated with percent canopy cover of cottonwood. Snags and dead limbs, loose bark, and cavities, all important roosting habitat for bats, were most prevalent in cottonwood stands; cavity-making birds (woodpeckers, nuthatches, chickadees) were also significantly more evident in cottonwoods. We conclude that naturalized Russian olive in the northern Great Plains is inferior riverine habitat for bats relative to native cottonwood gallery forest.

## Development Of A Regional Fence Model With Implications For Wildlife Management

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Barbed and woven wire fence are ubiquitous features across much of western North America, yet their effects on wildlife have received less attention than those of other anthropogenic features. At this time, no geospatial fencing data is available at broad level scales; potentially making wildlife modeling of vagile species less accurate and conservation planning less reliable at various scales. Here, we model fence density across 13 counties in Montana's Hi-Line region, based on publicly available GIS data and assumptions created from local, expert knowledge. The resulting fence location and density GIS layers are based on assumptions about where fence locations occur in association to different types of land tenure, land cover and roads. Locations of fences were collected via GPS along random 3.2 km long road transects ($n$ = 738) to assess overall model accuracy. Using a confusion matrix to determine variation between field and modeled fence locations, the total accuracy of the

model was 73% and Kappa was .40. Although we found inaccuracies associated with large parcels (>3 contiguous sections) of cultivated agriculture, our model is a promising step towards delineating fencing across the west. These general rules may be used and refined in the other areas based on the regional historical context. This new data may advance both wildlife research and management/mitigation activities. Using the relative density of fences across a region can prioritize conservation efforts at this broad scale. In addition, modeled fence locations provide useful and accurate information at a local scale.

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## Species-Specific Scaling To Define And Conserve The Northern Great Plains Region

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Prairie ecosystems are in a continuous state of flux, shifting by processes that include variable weather patterns and climatic conditions, disturbance regimes, and more recently, human-induced modification. Similarly, wildlife resources fluctuate across the landscape as a result of these ever-changing conditions; however, human alterations have increased, removed, and manipulated the ecological processes of the prairie. Specifically, the spatial scales at which humans manage and interact with the landscape are often inconsistent or incompatible with the scales required for the persistence of wildlife populations. Our synthesis demonstrates how the spatial scales at which wildlife in the Northern Great Plains of North America operate have been constrained by human intervention. This process of anthropogenic scaling has affected the decline of many native wildlife populations and in some cases has resulted in the complete extirpation of species from the landscape. We use historical observations and recent quantitative data to describe the primary cause of spatial scale alteration for prairie focal species (i.e. plains bison, pronghorn, grassland birds, Greater Sage-grouse, black-tailed prairie dogs, swift fox, prairie rattlesnakes) using migration, home range, distribution, and dispersal distances as metrics. We then describe the role that spatial scale plays in wildlife management of the prairie landscape from the non-profit, state, and federal perspective and how these entities are managing at the scales of each focal species.

## What Hunters Prefer And Value About Mule Deer Hunting In Montana

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During Montana's biennial process for establishing hunting seasons, Montana Fish, Wildlife & Parks (FWP) listens to issues, advocacies, opinions and values brought forward by diverse mule deer hunters. In recent years, vocal constituency groups have advocated for season structures that provide more opportunity to harvest mature mule deer bucks, reflective of the recent direction of mule deer management in much of the west. In an effort to better quantify the views and preferences of the Montana hunting public in general, FWP conducted surveys of both resident and nonresident mule deer hunters. Results from the survey confirm that mule deer hunting is very important to Montana's hunters, consistent with the fact that deer hunting is by far the most popular hunting activity in Montana. Approximately two-thirds of the survey respondents prefer less restrictive mule deer hunting regulations compared to more restrictive regulations that increase the probability of harvesting mature bucks by limiting opportunity. Surprisingly, trophy hunting was the least important reason expressed by survey respondents for hunting mule deer in Montana. Many respondents did express concerns about a variety of access related issues. Despite these concerns, respondents reported being generally satisfied with overall mule deer hunting opportunities in Montana, and nearly half of the respondents rated opportunities to hunt large mule deer bucks in the state as being better than average. FWP intends to use results from this survey in the consideration of future management of this important game species that is so highly prized by Montana hunters.

## Multi-Species Baseline Initiative: Getting The Most Bang For The Survey And Monitoring Buck

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Human dominated landscape change is occurring at unprecedented rates and there is much concern for how land use planners can help species remain resilient over time. However, for many species we lack a baseline understanding of the most basic of biological information such as range and distribution. Even a single survey of little known taxa groups can yield a wealth of information. For instance, our 2010 multi-species survey of 172 sites in the U.S. Selkirk Mountains yielded the first verifiable Idaho detection of magnum mantleslugs (*Magnipelta mycophaga*) in 68 years (17 specimens from 11 sites) and a higher than expected detection rate of the Idaho state imperiled (S2) fir pinwheel snail (Radiodiscus abietum) (105 specimens from 45 sites). Even species more charismatic than invertebrates often suffer from a lack of basic understanding. For instance, our 2010 Selkirk Mountain survey obtained the first verifiable lynx (*Lynx canadensis*) detection in the U.S. portion of that range in 18 years. The Multi-species Baseline Initiative (MBI) is driven by a diverse group of partners including not-for-profits, universities, tribes, state, and federal agencies. MBI's goals are to (1) describe the occurrence and distribution of multiple species, emphasizing species of greatest conservation need, in the Idaho Panhandle and adjoining mountain ranges and (2) implement a single long term monitoring plan for these species. We have divided our 23,825 km2 survey area into 953 5x5 km survey cells. During 2010 and 2011 we conducted 476 surveys for beetles, terrestrial gastropods, and forest carnivores at 476 (50%) of our survey cells.

## Infection And Immiunity In Bighorn Sheep Metapopulations: Dynamics Of Pneumonia

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It is widely accepted that reducing contact between domestic and wild sheep limits pneumonia introduction, where domestic sheep transmit pathogens to bighorns. However, in some places, pneumonia persists for many years, even as local domestic inholding decline. We focused on one such system, the Hells Canyon region. We used an extensive long-term dataset to assess the evidence that pneumonia-causing pathogens induce an acquired immune response in bighorn sheep by reconstructing pneumonia exposure histories, and evaluating the impact an individual's exposure history has on its survival. We found evidence of protective immunity lasting approximately two years, and saw that translocated individuals suffered much higher pneumonia risk than residents. Surviving many past pneumonia events decreased an adult's risk in future events, although lambs born to ewes with many past exposures were at higher risk than their peers. These results are consistent with a disease that produces some chronic carriers that shed to their lambs for many years. Interestingly, while we might expect that the impact of chronic carriage on a population should decline over time and allow for population recovery (through senescence of carriers), we instead saw a trend of increasing lamb pneumonia mortality. Our findings corroborate long-held hypotheses about the presence of a chronic carrier state, and suggest that better understanding specific mechanisms leading to chronic carriage will help clarify the costs and benefits surrounding various management strategies.

## Application Of Structured Decision Making To Elk Archery Regulation Decisions In Montana

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Prior to 2008, 22 hunting districts (HDs) in Montana had limited-draw, either-sex rifle permits, while the archery season was open for either-sex hunting to anyone possessing a general elk license. In addition, an unlimited number of hunters could obtain an either-sex archery elk permit in the 7 Missouri River Breaks HDs, where rifle hunting of bull elk is also limited. In 2008 the Montana Fish, Wildlife and Parks (MFWP) Commission implemented limited-draw archery regulations in these districts. These regulations have been very controversial since they were implemented. Certain public sectors have argued fervently for changes to these limited regulations in every MFWP season-setting process since 2008, and legislation that would reverse these regulations was introduced and defeated in the last two legislative sessions. In response to the contentious debate on this topic, in 2011 MFWP staff and the Montana Cooperative Wildlife Research Unit facilitated a 10-citizen working group composed of landowners, public sporting interests and commercial/fee hunting perspectives.

Using a Structured Decision Making (SDM) process, the working group developed a problem statement, fundamental objectives and assessed the performance of multiple archery season options relative to the fundamental objectives to arrive at an elk archery season proposal. In December of 2011 the MFWP Commission used these results as a basis for tentative season proposals that they distributed for wider public input and comment. Here we present the results of the SDM process and the working group proposal, as well as subsequent MFWP Commission action relative to the proposal.

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## A Comparison Of Wolf Depredation Sites In Areas With Migratory And Resident Elk

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As large carnivores recover in many wilderness areas and mixed-use landscapes, wildlife management agencies must seek ways to minimize private property damage while maintaining viable populations. Although much is known about carnivore-livestock conflicts, drivers of these processes in the Northern Rocky Mountains are still emerging amid the dynamic conditions of recovering predator populations (gray wolves [Canis lupus] and grizzly bears [*Ursus arctos horribilis*]), declining elk productivity, and the re-distribution of migratory and resident elk subpopulations. There has been little research to date that examines the influence of fine-scale elk distribution and movements on patterns of livestock depredation. In this study, we analyze four years of cattle depredation data, two years of summer and fall wolf predation data ($n$ = 4 wolves), and three years of elk movement data ($n$ = 86 elk) to assess the influence of migratory and resident prey on the location and occurrence of wolf depredations on cattle. Wolves living in migratory elk areas face low densities of their preferred prey in summer, when elk depart for higher elevations inside Yellowstone National Park (YNP), while wolves living in the resident elk area have access to abundant elk year-round. Wolves living in both areas have the potential to interact with several thousand head of cattle. We used logistic regression to compare the relative influence of landscape features on the risk of livestock depredation in the migratory and resident elk areas. Locations of wolf-killed cattle showed differences between the migratory elk area and the resident elk area. Depredation sites in the resident elk area were associated with habitats closer to roads and with high elk density, while depredation sites in the migratory elk area were associated with dens, streams, and open habitat away from the forest edge. Our findings indicate that knowledge of ungulate distributions and migration patterns can help understand and predict hotspots of wolf conflict with livestock.

## The Effects Of Changes In Elk Archery Regulations On Elk Hunter Effort And Harvest, 2004-2010

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We evaluated the effects of changes in elk archery hunting seasons in eastern Montana on hunter numbers, days, and densities and elk harvest. We compared 2 time periods (2004-2007 and 2008-2010) and grouped hunting districts (HDs) into 1 of 4 season types. The 4 season types were limited permits in the Missouri Breaks (7 HDs), limited permits in non-breaks HDs (22 HDs), adjacent HDs were in close proximity to the limited permit HDs that we hypothesized might receive additional hunters displaced from the two more restrictive archery permit areas (22 HDs), and our pseudo-control season type included the rest of the HDs in the state (110 HDs). It appeared, from a statewide perspective, that changing the archery regulations to limited permits in 27 HDs didn't cause a statistically significant hunter shift to the 22 HDs identified as areas hunters would likely select if restrictions forced them to choose a new area. The only significant changes in hunter numbers and days were decreases in non-resident hunter numbers and days in the Missouri River Breaks HDs. Although the decrease in non-resident use may have had an economic impact in the local area; statewide, there was no change in non-resident use. Pseudo-control HDs showed decreases or no change in harvest response variables. Therefore, the significant harvest increases and/or lack of significant harvest declines in the limited permit areas might be interpreted as a relative success since most of these hunting districts are above population objectives for elk.

## Using Occupancy Surveys to Assess Summer Resource Selection of Sympatric Bighorn Sheep and Mountain Goats in Northern Yellowstone

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Both bighorn sheep and mountain goats are generalist herbivores that overlap extensively in broad food and habitat requirements, but there have been few studies examining the potential for competition between sympatric populations. One area in which native bighorn sheep are living in sympatry with non-native mountain goats is the southern Gallatin Mountain range within and adjacent to the northwest boundary of Yellowstone National Park. Existing data of bighorn sheep and mountain goat observations for the area vary in spatial precision and records of areas where observers looked for but did not detect animals are not available. To gain a better understanding of the relationship between bighorn sheep and mountain goats and their habitat, it is necessary to understand resource selection and the extent of overlap in resource use among sympatric populations on fine spatial and temporal scales. In order to meet this need we designed and implemented formal, ground-based occupancy surveys during the summer of 2011. A crew of four spent 113 observer days in the field and hiked approximately 210 miles recording presence-absence data for both mountain ungulates. A total of 6,932 sample units were surveyed, with 68 bighorn sheep and

95 mountain goat groups detected. Detection probabilities for bighorn sheep and mountain goats were 66.9% and 54.5% respectively. We summarize the objectives and field design of the project and report on our efforts to develop enhanced habitat models which will provide managers with additional ecological insights.

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## Use Of A Human Disturbance Model To Assess Impacts Of Anthropogenic Development On Wildlife

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In an effort towards developing consistent and reliable methods for addressing the impacts of subdivision development and other anthropogenic disturbances on wildlife, I developed a GIS model to predict the extent and magnitude of human-caused disturbance. The model estimates cumulative disturbance from point and linear sources, produces output at a fine scale to provide comparisons of different development configurations, and allows variability of input parameters depending on the species of interest. Output can be used for a standalone analysis or used in conjunction with habitat models to assess reductions in habitat quality or connectivity value resulting from human disturbance. Examples of model output are presented to illustrate how the model has been previously used in the planning and assessment processes and how it can also be used to assess impacts of energy development.

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## Hierarchical Foraging Ecology Of Yellowstone Bison And Development Of Remote Sensing Techniques For Management Of Bison And Other Herbivores Across The Intermountain West

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To help address the controversy concerning movement of bison outside Yellowstone National Park and identify potential areas for bison relocation, we determined seasonal foraging habitat selection by bison at 4 hierarchical levels, the dominant hierarchical level of selection by Yellowstone bison, inter-annual consistency of use of grazing locations, and developed remote-sensing techniques for determining spatio-temporal estimates of herbaceous vegetation availability and forage utilization at a landscape scale. Without accounting for differences in sward biomass among vegetation types, selection of vegetation types was inconsistent among hierarchical levels. However, development and use of a biomass index accounted for differences in offtake rate among vegetation types that resulted in consistent selection across hierarchical levels for upland vegetation types over mesic lowland types. Monitoring of known feeding sites over successive years further indicated preference of upland vegetation types. Results suggest the feeding site level as the dominant level of selection and that Yellowstone bison exhibit behavior expected of energy maximizers in both the short- and long-term. Remote sensing techniques providing spatially-explicit estimates of standing crop of herbaceous vegetation were developed at 4 locations across diverse habitat in MT and Yellowstone Park, WY. Estimates of forage utilization were developed for the Yellowstone Park location. Results of this project increase our understanding of the spatial and temporal dynamics of bison foraging ecology both inside and outside Yellowstone

National Park and offer remote-sensing techniques relevant to the management of all grazing herbivores throughout the intermountain west.

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## The Blackleaf Wildlife Management Area: 30 Years of Vegetation Monitoring

Gary Olson, Montana Department of Fish, Wildlife and Parks

Changes in native plant community cover and composition are generally gradual and affected by multiple environmental factors. Detection of vegetative trend can be difficult without long-term data collection efforts. Management of the Blackleaf Wildlife Management Area includes emphasizing the occurrence of highly productive, diverse plant communities that provide the best possible forage and cover for native wildlife species. To help accomplish this management goal, a range condition and trend survey was initiated shortly after purchase of the property to establish baseline vegetative condition. Fourteen permanently marked transects were established and species' cover values monitored every four years from 1979 - 2009. The area was rested from livestock grazing from 1979 - 1989; a non-traditional rotational grazing system was initiated in 1990. Rough fescue (*Festuca scabrella*), Hood's phlox (*Phlox hoodii*) horizontal juniper (*Juniperus horizontalis*) and shrubby cinquefoil (*Potentilla fruiticosa*) were selected as indicator species that reflect overall plant community trend. Response of grasses, forbs and shrubs over the 30 year period are discussed, as well as individual species' trends. In general, while total plant cover remains static, grasses are increasing, forbs are declining. Vegetative response to a long-term rest livestock grazing system is presented as well.

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## Genetic Population Structure Of Mule Deer *Odocoileus Hemionus* Across Montana

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We conducted a genetic assessment of mule deer (*Odocoileus hemionus*) population structure across Montana in an effort to understand dispersal routes across the landscape. To assess genetic structure we genotyped 14 microsatellite loci in 359 individuals sampled primarily within Montana. Smaller samples were included from Wyoming, Colorado and Utah in order to provide a regional context for the levels of population structure observed within Montana. Additionally, we sequenced the control region of the mitochondrial genome of 76 individuals subsampled from our original samples across Montana. To avoid potential influences of a priori population designations, individual based analyses were used to test relatedness across the landscape. Weak isolation by distance characterized mule deer individuals across this region. In addition, we did not detect any evidence of spatial autocorrelation in discrete distance classes as small as 10 km. Female mule deer had higher average individual pairwise genetic distances than males, indicating the presence of a

contemporary male bias in dispersal rates. Mitochondrial DNA indicated the potential for either reduced overall or female-specific dispersal between a subset of the sampling regions within Montana. Finally, we were unable to detect a genetic signature of past translocations of mule deer across Montana. Taken together these results indicate that within this landscape mule deer populations are characterized by high levels of connectivity and experience few, if any, barriers to dispersal.

## How Well Can We Predict Wildlife Corridors? Tests Of Alternative Modeling Approaches In Migratory Elk And Dispersing Wolverines

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Landscape connectivity has become a key focus of conservation biology as natural habitat is increasingly fragmented by human land use. Several landscape modeling approaches are now relied upon to identify likely dispersal and migration corridors and guide conservation planning. However, the predictive accuracy of these methods has seen limited testing against empirical movement data, which limits confidence in their utility and confuses selection of appropriate methods for a given application. To address these issues, we used GPS collar data from migrating elk and dispersing wolverines to evaluate the ability of common modeling approaches (cost-distance/least-cost path models and circuit theory models) to predict observed movement routes. While both methods made generally similar predictions, cost-distance models consistently outperformed circuit theory models, and predictive success was much higher for elk than for wolverine movements. Furthermore, the form and complexity of underlying landscape resistance maps influenced model performance and revealed unforeseen differences between models. These findings illustrate that corridor model performance depends greatly on focal species and landscape characteristics as well as selection of appropriate methods for the application at hand.

## Trumpeter Swan Production And Habitat In The Centennial Valley, Montana

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The Trumpeter Swan Society (TTSS) initiated a pilot project in 2011 in the Centennial Valley to document existing conditions on historic trumpeter swan nesting territories. Swan production in the Greater Yellowstone region surrounding Yellowstone National Park has declined significantly over the past fifty years, particularly in the Centennial Valley, Montana, which historically has been the primary production area in Greater Yellowstone. Current low production raises serious concerns over the viability and sustainability of trumpeter swans in the Centennial and the entire region. The lack of a long-term comprehensive restoration strategy for Greater Yellowstone nesting swans, and particularly the changing management emphasis on Red Rock Lakes NWR, further emphasize the need to improve swan production in the Centennial Valley. Apparently suitable nesting territories are available and may be occupied but production is not occurring, and a growing number of non-breeding adult swans

are present. Lima Reservoir is the dominant water feature in the lower half of the Valley but widely fluctuating water levels affect quality waterfowl habitat, including some swan nesting territories and areas used intermittently by up to 150 non-breeding trumpeter swans. In cooperation with the Centennial Valley Association which represents 30 landowners in the Valley, TTSS monitored swan production and collected basic wetland information on the 15 most frequently used trumpeter swan territories outside Red Rock Lakes NWR. In some years, these territories have surpassed refuge swan production. This effort documented swan use and characteristics of nesting territories including wetland type and water availability, availability and quality of emergent and aquatic vegetation, and human influences such as livestock grazing, presence of fences in the wetland, and potential disturbances. Potential wetland enhancement projects were identified that could encourage trumpeter swan use. Trumpeter swan monitoring and site-specific habitat assessments are planned for the next 3-5 years.

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## Documenting Basline Winter Activity Levels Of Bats In Montana With Acoustic Monitoring

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We deployed acoustic monitoring stations at 3 locations (Lewis & Clark Caverns, Toeckes Cave, and McDonald Mine) in Montana from January through mid-May, 2011. The goal of this monitoring effort was to document winter base-line activity data to potentially use acoustic monitoring as a surveillance tool for White-nose syndrome (WNS). Each monitoring station was equipped with an Anabat detector, temperature data logger, and solar panel array to allow long-term, remote monitoring. The monitoring stations recorded bat activity (bat passes) and temperature outside of hibernacula. External monitoring minimized potential human disturbance to the hibernating bats or any potential spread of *Geomyces destructans*, the fungus responsible for WNS. Studies conducted by Bat Conservation International at White-nose syndrome affected hibernacula in the eastern U.S., have shown dramatic increases in activity levels at WNS vs. non-infected WNS sites during the hibernation period. If this pattern also holds true in the western U.S., documenting pre-WNS baseline activity levels may allow for acoustic monitoring as a surveillance tool for potential spread of WNS.

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## Evaluating Aspen Responses To Changes In Elk Abundance, Distribution And Behavior Following Wolf Reestablishment In West-Central Yellowstone National Park

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The reintroduction of wolves to Yellowstone National Park created a unique "natural experiment" to study trophic interactions in a large-scale terrestrial system among wolves, elk, and aspen. This study utilized data from a long-term elk demography study that was established prior to wolf reintroduction. Significant changes in the abundance and distribution of the Madison headwaters elk herd were observed following wolf reestablishment. The spatial arrangement of these changes made it possible to directly test for the occurrence of a density-mediated trophic cascade. The objectives of this study were to answer the following questions: 1) was there a marked decrease in browsing pressure on aspen where elk densities declined, and 2) was there a corresponding plant-growth response indicating that aspen were released from browsing pressure? Historical browsing conditions and aspen height were observed for 31 aspen stands to assess the occurrence of a density-mediated trophic cascade following wolf reintroduction. Browse conditions and aspen morphology in stands where elk densities declined dramatically following wolf reintroduction were compared to stands that experienced persistent heavy browsing throughout this period. A major decline in browsing pressure along with a modest increase in aspen height and leader longevity was detected, supporting the hypothesis of a density-mediated trophic cascade. However, the magnitude of the growth response was weak, suggesting that browsing was not the dominant limiting factor to aspen growth in the study area and that aspen may be more strongly limited by bottom-up regulation.

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# Developing Priorities For The Great Northern Landscape Conservation Cooperative: State Wildlife Action Plans (SWAP) As One Piece Of Information

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Landscape Conservation Cooperatives (LCCs) are public-private partnerships that focus on natural resource challenges which transcend political and jurisdictional boundaries and require a more holistic, collaborative, and adaptive approach to conservation that is firmly grounded in science and strives to ensure the sustainability of land, water, wildlife and cultural resources. The Great Northern LCC, covering Western Montana and parts of several other states and provinces, is nearing completion of a process that synthesizes conservation priorities among the 25 organizations represented on the Steering Committee and their partners. This Strategic Conservation Framework identifies priority species, ecosystems, and ecosystem processes across the landscape represented by the Great Northern LCC based on synthetic summarizations of five state-based Wildlife Action Plans, 40 other regional conservation planning documents, and focused interviews with key personnel across the region. Here we report on the process by which we analyzed data from the State Wildlife Action Plans (SWAPs) of ID, MT, OR, WA, and WY and from Strategic Habitat Conservation as one piece of information for strategic planning. Thirty-five species of greatest conservation need (as defined in the SWAPs) were identified as having commonality across the five states.

The ranges of these species were then overlain and a map of areas with the greatest number of species of conservation need can be visualized across the Great Northern LCC.

## BLM's National Greater Sage-Grouse Planning Strategy — What it Means for Montana

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The Bureau of Land Management (BLM) is responsible for managing over 50% of the remaining Greater Sage-Grouse habitat throughout their range. In July, 2011 the BLM National Greater Sage-Grouse Planning Strategy was released as a supplement to the 2004 BLM National Sage-Grouse Habitat Conservation Strategy and the 2006 Western Association of Fish & Wildlife Agencies (WAFWA) Greater Sage-Grouse Comprehensive Conservation Strategy. This was in part due to the March 2010 petition decision by the U.S. Fish and Wildlife Service as "Warranted but Precluded" and settlement discussions between the FWS and Nongoverment Organizations (NGOs) over candidate species. The listing decision identified inadequate BLM regulatory mechanisms as a major factor in this decision. Principle regulatory mechanisms are conservation measures in Resource Management Plans (RMPs). Habitat for the Greater Sage-Grouse is found within five planning units in Montana. In December 2011 BLM issued instruction to offices on; 1) how BLM is to manage activities occurring within habitat for the Greater Sage-Grouse until RMPs amendments or revisions are completed, and 2) management actions and conservation options to be considered when developing RMP amendments or revisions. RMPs are to be completed or revised by December, 2014. This direction identifies actions for BLM programs with the potential to impact Greater Sage-Grouse. BLM is committed to reducing threats to Greater Sage-Grouse habitat on BLM lands in Montana through changes in management.

## Determining The Influence Of Hunter Access On Antlerless Elk B License Harvest In Select Areas Of Southwest, Central and Eastern Montana

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Antlerless elk hunting is a critically important tool for wildlife managers to help manage populations of elk. Montana Fish, Wildlife & Parks (FWP) conducted a survey following the 2010 general big game hunting season to determine the effect that hunter access might have on Antlerless Elk B License utilization and associated harvest in select areas of the state where concerns have been expressed about hunting access. A mail-back survey was used to determine, the extent to which respondents were able to gain access to public and private lands to hunt antlerless elk, what types of properties respondents were able to secure permission to hunt, the extent to which respondents were able to successfully harvest antlerless elk, and respondent satisfaction with the Antlerless Elk B Licenses they received in

2010. Questionnaires were successfully mailed to a total of $N$ = 5,297 Elk B License holders and there were a total of $n$ = 2,954 survey respondents resulting in an overall response rate of 56 percent. Survey results revealed several key findings that have significant elk population management implications. While respondents used different hunting access or property types to varying degrees the type of property accessed played a prominent role in determining antlerless elk harvest success rates and antlerless elk harvest distribution. A majority of the survey respondents who hunted or attempted to hunt using their Antlerless Elk B License reported that they were satisfied with the license they received in 2010.

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## Occupancy Dynamics, Roost Habitat and Prey of Mexican Spotted Owls in Utah

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Mexican spotted owls (*Strix occidentalis lucida*) occupy canyon habitats that have received less attention than owls in forested environments, and yet canyon environments represent a significant portion of the owl's range. In Utah, the owls occupy narrow and steep-walled canyons that attract high levels of human use, including climbing and hiking through nest areas, and human use levels have strongly increased in the canyons, for example, permits for access to popular climbs and hikes increased over 1700% during 1998 to 2002 in Zion National Park. To examine potential effects of recreation on the owls, we studied temporal variability of detection, occupancy, local extinction, and colonization probabilities. Our study sites included several National Parks and BLM resource areas. Our primary objective was to examine effects of recreation on site occupancy dynamics. We also investigated reproductive success, roost habitat, and prey selection. The analysis of detection rate showed strong support for constant detection probability of 89% for spotted owls among 47 sites. For both single owls and owl pairs we estimated initial occupancy rate of 83% for mesic sites and 43% for relatively xeric sites. We found that recreation was not associated with occupancy, detection, nor extinction and recolonization probabilities. Although reproductive rates varied by year, recreation was not negatively associated with production of fledgling owls per site. We also studied prey selection and roost habitat in the canyon environments. Roosts were placed on steep-walled cliffs with greater number of perches than adjacent habitats, and roosts possessed relatively high overhead tree cover, cool daytime temperatures, and thus a suitable thermal environment in the arid canyons. Pellets collected at roosts sites, upon dissection, indicated that rodents were primary prey, but also included birds, bats, and various anthropods. Woodrats (Neotoma sp.) dominated the prey frequency and biomass.

# POSTERS

## MECHANISMS DRIVING NONNATIVE PLANT-MEDIATED CHANGES IN SMALL MAMMAL POPULATIONS AND COMMUNITIES

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Nonnative plants can dramatically alter habitat of native animals through changes in vegetation structure and availability of food resources. Range expansion by nonnative cheatgrass (*Bromus tectorum L.*) is an acute threat to persistence of native species in the sagebrush-steppe ecosystem of southwestern Montana. As climate changes over the next century, rangelands in Montana are likely to become more hospitable to this invasive grass. Although declines in small mammal diversity and abundance previously have been documented with cheatgrass invasion, we know little about the underlying mechanisms driving these changes. We will explore potential mechanisms for nonnative plant-mediated changes on three species of native mammals: deer mouse (*Peromyscus maniculatus*), montane vole (*Microtus montanus*), and sagebrush vole (*Lemmiscus curtatus*) in sage-steppe communities at the Gravelly-Blacktail Wildlife Management Area (WMA). We will quantify changes in vegetation characteristics in areas invaded by cheatgrass; based on this information, we will develop experimental treatments that mimic individual modified characteristics. We will apply these treatments to randomly selected plots on the WMA and establish appropriate controls. Using standard capture-mark-recapture methods, we will estimate abundance and species diversity of small mammals and make comparisons between treated and control plots to quantify effects. We will also quantify and compare body condition, predator avoidance, and diet to explore additional mechanisms driving changes in mammalian abundance and diversity. Identifying the mechanisms for how cheatgrass invasion alters populations and communities of native species will provide critical information to inform conservation and management of some of Montana's native small mammals.

## CITIZEN SCIENTISTS ADD TO OUR UNDERSTANDING OF BIRD POPULATIONS AND STATUS ACROSS MONTANA

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Montana Audubon, our partners, Audubon Chapter members, and bird enthusiasts across the state are increasingly involved in contributing time and talents to understanding bird populations, habitat associations, and trends. Birders contribute sightings to eBird or Tracker, reporting their observations from field excursions and their backyards. This information helps inform Montana Species of Concern listings and influences bird conservation and science priorities in the state and beyond. Montana Audubon also encourages citizen monitoring projects for single species and guilds, from Black Swifts to nightjars. We are now home to the Greater Sage-grouse Adopt-a-Lek program which coordinates citizen scientists to monitor sage-grouse on over 50 breeding leks across Montana every spring. Finally, our Audubon

chapters adopt and monitor Important Bird Areas across the state in order to conserve species of conservation concern and their habitats. Find out more about all these volunteer efforts.

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## Good Animals In Bad Places: Evaluating Landscape Attributes Associated With Elk Vulnerability To Wolf Predation

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Vulnerability of prey to predators is heavily influenced by their respective physical and behavioral characteristics; however their interactions with landscape, and climate, collectively termed "environmental vulnerability," may also assume considerable importance. Little is known about the impact of environmental vulnerability in large mammal systems, where post-encounter vulnerability may assume more importance than encounter probability. This study utilized 18 years of survival and mortality data for radio-collared elk (*Cervus elaphus*), in concert with abundance, distribution, and habitat use data prior to and following restoration of wolves (*Canis lupus*) to Yellowstone National Park to evaluate the relationship between environmental attributes and elk mortality. We modeled the odds of mortality for 108 elk in 1257 animal sample intervals from 1991-2009 across a range of environmental conditions and gradients of wolf predation risk to evaluate: 1) The relationship between landscape, habitat, and environmental attributes and elk vulnerability to wolf predation and 2) Changes in the attributes related to elk mortality before and after wolf colonization. In the absence of wolf predation, mortality risk for elk was primarily associated with physical attributes of elk known to influence starvation mortality. Following wolf reintroduction mortality risk was more strongly associated with characteristics of the landscape and climate within an animal's home range. These environmental influences resulted in substantial changes in distribution and abundance of elk in the study system and suggests environmental heterogeneity may have an important influence on wolf and elk distributions and dynamics.

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## Wildlife Barrier Fences And Pronghorn Habitat Conectivity Concerns In Eastern Montana

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Historically, eastern Montana was one of the largest sheep producing regions of the west. Although sheep production has decreased dramatically in the past three decades, several hundred miles of woven-wire and sheep tight fences continue to dissect this landscape. These fences are known to hinder wildlife movement patterns, cause entanglement mortality and

interrupt daily and seasonal habitat use. Miles City Field Office Bureau of Land Management (MCFO BLM) has removed 83 miles of such wildlife barrier fences since 2004. A more wildlife friendly, four-wire fence is constructed to maintain livestock distribution while reducing impacts to wildlife, most notably, pronghorn movements. Since 2009, 57 miles of wildlife barrier fences have been removed and modified, of which 47 and 29 miles were within crucial mule deer and pronghorn winter range. Since 2004, nearly $100,000 of contributed funds and materials have been provided through partnership with MCFO permittees. These funds have resulted in additional miles of barrier fence being removed on deeded lands. Interagency efforts in 2010 with Montana Fish, Wildlife and Parks led to an agreement with TransCanada Pipeline Company to ensure the removal of 23 miles of wildlife barrier fences on deeded lands in southeastern Montana. MCFO continues to identify wildlife barrier fences for removal and pursues partnerships in an effort to address habitat connectivity concerns at a landscape scale.

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# Soil Modification As A Restoration Tool To Reduce Old World Bluestems In Texas Coastal Prairies

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Nonnative Old World bluestem (OWB) grasses (e.g., *Bothriochloas, Dichanthium* spp.) have become dominant throughout the southern and central Great Plains, altering native plant communities and habitat quality for wildlife. Although conventional management strategies have not resulted in elimination or reduction of these grasses, modifying soil conditions to favor native plants may be an alternative restoration tool. We examined efficacy of 10 soil modification treatments (soil disturbance alone, pH increase, pH reduction, carbon addition, addition of soil mycorrhizae, and each combined with seeding of native vegetation) on 60 research plots at the Welder Wildlife Foundation Refuge in southern Texas in summer 2011. We sampled soil chemistry, vegetation density, cover, and height, and abundance of soil, terrestrial, and flying arthropods four and eight weeks after initial treatments. Severe drought prevented plant growth on treated plots and may have decreased the efficacy of soil treatments, especially pH reduction. As such, we compared vegetation and arthropod communities only between undisturbed plots dominated by native vegetation and dominated by OWBs. Species richness of vegetation was higher on plots dominated by native vegetation (4.4 species/m$^2$, $SE$ = 0.6) compared to plots dominated by OWBs (2 species/m$^2$, $SE$ = 0.5). Arthropods were more abundant in native vegetation (175 individuals/m$^2$, $SE$ = 4.1) relative to OWB-dominated plant communities (41, 1.3). Isopods and ants were the most abundant groups overall, although some of these taxa are nonnative. We will continue to collect data over the next two years to explore further soil modification as a restoration tool in grasslands impacted by OWBs.

# Nesting Habitat And Behavior Of Spiny Softshell Turtles *Apalone Spinifera Hartwegi* In The Missouri River, MT

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Little is known about the nesting behavior and habitat of the western spiny softshell (*Apalone spinifera hartwegi*) in Montana where they are at the northern extent of their range and are a state Species of Concern. Our objective was to document nesting behavior, habitat, and timing in a 97-kilometer reach of the Missouri River. We radio-tagged 47 female turtles and attempted to locate nesting areas using telemetry, visual surveys from jet boat and on foot, and by observation from shore-based blinds. We located 27 nests; 15 were on islands, 12 were aggregated, and 2 were depredated. Nesting occurred following the peak river stage from about July 7 to July 28. Twenty-three nests were in mixed gravel and 4 nests were in sand substrates. Distance from water's edge to the nest ranged from 1.9 m to 27 m and height of nest above the water surface elevation ranged from 0.25 m to 1.9 m. Vegetation at nest sites was sparse, ranging from 0 to 15 percent vegetative cover. Emergence of hatchlings was documented for 17 nests and occurred from about September 1 to September 20. All 17 successful nests were in gravel substrate; we did not document any emergence from nests in sand. Lack of emergence from sand nests may be related to the cumulative thermal regime in the nest chamber during the period from peak discharge until the onset of freezing in autumn. In 2012, we will investigate the thermal environment in gravel and sand nesting substrates.

# How To Attract A Loon

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Prospecting is a behavior observed in many species when breeding territories are limited. This behavior has been observed in Common Loons. Yet, in Montana there are an abundance of unoccupied territories and competition for occupied territories is still fierce. we used Common Loon decoys and calls to find out if we could attract non-breeding loons to unoccupied territories. We found that there is a pattern between a loon landing on a territory and the presence of loon decoys ($p = 0.11$, $n = 42$). We also discovered a more expedient way ($p = 0.05$) to collect loon band observations using the decoys ($n = 14$). The data collected will be helpful in understanding loon behavior and will help guide future management actions.

# Managing Montana's Golden Eagles In A Landscape Of Development: A Collaborative Approach

Catherine S. Wightman, Montana Fish, Wildlife and Parks, PO Box 200701, Helena, MT 59620 on behalf of the Montana Golden Eagle Working Group

The Montana Golden Eagle Working Group, an active coalition of agency representatives and eagle experts, was convened in April 2011 to address information needs and management recommendations for Golden Eagles in the state. Current data indicates Golden Eagle populations may be declining across the western United States and stable or declining in Montana. New energy and subdivision development may exacerbate these population trends through direct mortality, indirect and direct habitat loss and alteration, and increased disturbance. However, we lack information that is necessary to evaluate population-level impacts of new development. In 2009, the U.S. Fish and Wildlife Service (USFWS) published a final rule authorizing limited issuance of permits to take Bald and Golden Eagles where the take is consistent with the goal of increasing or stable breeding populations, is associated with and not the purpose of an otherwise lawful activity, and cannot practicably be avoided despite the implementation of advanced conservation practices. Consequently, limited take of eagles may be authorized relative to energy development or other activities while managing for no net loss to the population. This means the USFWS must identify potential eagle mortality sources, the impact of potential mortality on the population, and impact avoidance, minimization, and compensatory mitigation strategies. The Golden Eagle working group is drafting a monitoring strategy and management recommendations for Golden Eagles in a landscape of development. Here we provide information on working group activities which are focused on allowing for continued development while simultaneously conserving one of Montana's most charismatic birds.

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