Intermountain Journal of Sciences

(ISSN 1081-3519)

Vol. 22, No. 4 - December 2016

IJS

Intermountain Journal of Sciences

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

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

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

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

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

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

*For detailed information about IJS, please go to our web site at:
www.intermountainjournal.org

ISSN #1081-3519

Intermountain Journal of Sciences

Financial Statement (1/01/16 - 12/31/16)

Balance 01/01/16		**$1,231.35**
Income:		
Subscriptions:		
Regular Member		60.00
Library Subscriptions		225.00
Life Member		300.00
International Member		25.00
	Subscriptions Total	**$610.00**
Page Charges		7,400.00
Reprints and PDFs		319.96
Refund		.08
Back Issues		8.00
Sponsoring Organizations for MSU Lib Services		1,500.00
Total Income		**$9,838.04**
Expenses:		
Design and Printing		$4,083.40
Mailing and Postage		$196.31
P. O. Box Rent		$130.00
Administrative and Bank Fees		$117.50
Reprints & PDFs Layout		$323.85
Storage		$377.00
Website Domain Name - 3/2014 - 3/1017 (3 years)		37.44
Website hosting - 5/24/2013 - 5/24/2018 (5 years)		465.10
Total Expenses		**$5,730.60**
Balance 12/31/16		**$5,338.79**

Fred Nelson, Business Manager

Editorial Review Policy

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

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

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

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

Acceptance

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

Rejection

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

Reviewer Anonymity

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

Manuscripts Submitted by Editors

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

Abstracts

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

Commentary

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

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

Literature Cited

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

Send all manuscripts to: Editor-in-Chief, P.O. Box 3014, Bozeman, MT 59772-3014
or through the IJS website (www.intermountainjournal.org) under the Publish tab.

Diet of Juvenile Burbot and Insight into Gape Limitation

Zachary B. Klein*, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive, Moscow, Idaho, 83844-1141, 303-249-4190

Ryan S. Hardy, Idaho Department of Fish and Game, 2885 West Kathleen Avenue, Coeur d'Alene, Idaho, 83815

Michael C. Quist, U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit, Department of Fish and Wildlife Sciences, University of Idaho, 875 Perimeter Drive, Moscow, Idaho, 83844-1141

Abstract

Throughout much of their distribution, Burbot (*Lota lota*) populations are declining or have been extirpated. Burbot in the Kootenai River, Idaho represent one such imperiled population. In an effort to restore Burbot in the Kootenai River, managers have turned to conservation aquaculture. However, no appreciable increase in natural recruitment has been observed in the system. The lack of natural recruitment is believed to be partly due to a deficiency of high-quality prey. As a result, we sought to i) describe the diet of juvenile Burbot, ii) evaluate the influence of Burbot mouth gape on diet and iii) estimate prey availability at release locations. Burbot were stocked into two earthen ponds at the Boundary Creek Wildlife Management Area (BCWMA) and sampled weekly to evaluate diet. Zooplankton were sampled weekly from each pond and from release locations of hatchery-reared Burbot (i.e., Kootenai River, Goat River, Boundary Creek, Deep Creek) to quantify prey availability. Over the course of the study (~3 months), Burbot primarily fed on Cyclopoida. Burbot never appeared to be gape limited and exhibited little variability in the size of zooplankton ingested. Zooplankton densities at stocking locations were relatively low in comparison to BCWMA ponds. Low zooplankton densities at release sites indicate that alternative management actions may need to be considered to enhance Burbot recruitment in the Kootenai River drainage.

Key words: Burbot, Diet, Kootenai River, Gape

Introduction

Burbot (*Lota lota)* are the only freshwater member of the family Gadidae (Howes 1991). They have a holarctic, circumpolar distribution that rarely extends below 40°N latitude. Throughout much of their distribution, Burbot populations are either declining or have been completely extirpated (Arndt and Hutchinson 2000; Paragamian et al. 2000). Declines are especially evident in populations at the southern extent of the species' distribution (Dixon and Vokoun 2010). In Idaho, the Kootenai River (Kootenay in Canadian waters) represents one such imperiled population. Historically, the Kootenai River supported subsistence, commercial and recreational fisheries for Burbot. In the later part of the 20th century, Burbot populations began to decline resulting in the eventual closure of the fishery in the 1990s (Paragamian et al. 2000). Burbot numbers continued to decline and a committee, the Kootenai Valley Resource Initiative (KVRI), was created and tasked with developing a conservation strategy to restore Burbot in the Kootenai River (KVRI Burbot Committee 2005). One of the primary restoration measures identified by the KVRI was the use of conservation aquaculture to reverse population declines of Burbot. Although the conservation strategy outlined rehabilitation actions, it did not provide population-level targets that were necessary to restore Burbot in the Kootenai River. In response, Paragamian and Hansen (2009) used density-dependent

population models to define management targets necessary to recover Burbot in the system. The authors suggested that 17,500 individuals (143 fish/km) producing 1.1 recruits/year was necessary to achieve a self-sustaining population. However, the management goals outlined by Paragamian and Hansen (2009) assumed the occurrence of natural recruitment. Although over 1,500,000 hatchery-reared Burbot have been released in the Kootenai River drainage from 2009–2015, no appreciable increase in natural recruitment has been observed.

Low availability of quality prey has been suggested as contributing to the lack of natural recruitment of Burbot in the Kootenai River. Prey limitations have been considered to be one of the major causes of recruitment failure in fishes for over a century (Hjort 1914). Cushing (1969, 1990) hypothesized that a asynchrony between peak larval fish abundance and their prey would result in decreased recruitment success (Match-Mismatch Hypothesis). Although the Match-Mismatch Hypothesis (and similar hypotheses) has been extensively investigated, the exact mechanisms underlying recruitment success of larval fishes are rarely identified (Anderson 1988). Notwithstanding, the significance of appropriate prey to larval and juvenile fish is an important consideration with regard to growth, survival and recruitment to a population (Crowder et al. 1987; Graeb et al. 2004; Garvey and Chipps 2012). If one assumes that prey availability is at least partially responsible for regulating recruitment in fish populations, then the identification of available and appropriate prey in natural environments is critically important for the management of imperiled fishes. Therefore, the goals of the current study were to i) describe the diet of juvenile Burbot, ii) evaluate the influence of Burbot mouth gape on diet and iii) estimate prey availability at release locations.

Methods

The Kootenai River is the second largest tributary to the Columbia River and supports Idaho's only native Burbot population. The Kootenai River originates in Kootenay National Park, British Columbia, Canada. From its origin, the river flows south into the United States where it is impounded by Libby Dam near Jennings, Montana forming Lake Koocanusa (Knudson 1994). Thereafter, the river flows through the northwest corner of Idaho before returning to Canada. In Idaho, three major tributaries of the Kootenai River (Boundary Creek, Deep Creek, Goat River) have been identified as important rearing habitats for juvenile Burbot. As such, each tributary has been the focus of intensive stocking of juvenile Burbot. Burbot were released in Boundary Creek less than 1 km from its confluence with the Kootenai River near the Canada-Idaho border. In Deep Creek, Burbot are stocked 21–33 km from its confluence with the Kootenai River near Bonners Ferry, Idaho. Burbot have been released at various locations throughout the Goat River.

In February 2012, adult Burbot were sampled from Moyie Lake, British Columbia using baited cod traps and angling (Spence 2000; Neufeld and Spence 2004). Burbot were spawned on site and fertilized eggs were transported to the University of Idaho's Aquaculture Research Institute, Moscow, Idaho. Burbot were reared using standard techniques (Jensen et al. 2008) and hatched from March 20–26, 2012. Burbot were reared for approximately 40 days and then transferred to the Boundary Creek Wildlife Management Area (BCWMA) ponds. The ponds are located on the west side of the Kootenai River valley near Porthill, Idaho. Each pond ($n = 2$) was excavated in 2010 and measures approximately 25 × 15 m. Both ponds are roughly 3.5 m deep and fill naturally through run off and seepage. On May 1, 2012, about 10,500 larval Burbot (~10.0 mm total length) were stocked in each pond (0.01 fish/L). From May–July, up to ten juvenile Burbot were sampled weekly to evaluate diet and growth. Juvenile Burbot were sampled with vertical hauls of a D-ring net (750 µm mesh) and preserved in 90% ethanol. Concurrently, zooplankton were sampled in triplicate from

each pond to evaluate prey availability. Zooplankton were sampled using vertical tows of a Wisconsin-style plankton net. The net measured 0.3 m in diameter and was constructed of 80 µm mesh. Additional zooplankton samples were collected from the Kootenai River and Boundary Creek to evaluate prey availability at release locations. Zooplankton in the Kootenai River and Boundary Creek were collected in triplicate using 18.9 L grab samples, that were filtered through 80 µm mesh. All zooplankton samples were immediately preserved in 10% Lugol's solution. Burbot and zooplankton samples were transported to the University of Idaho for analysis. In July 2012, both ponds were drained and remaining Burbot were removed and released into Boundary Creek. In 2013, adult Burbot were collected and juveniles were reared following the same techniques used in 2012. Burbot hatched from March 27–April 5 and were transferred to the BCWMA ponds approximately 50 days later. On May 22, 2013, approximately 50,000 larval Burbot were stocked into each pond (0.04 fish/L). Larval Burbot and zooplankton were sampled in the same manner as in 2012. Ponds were drained in late July and remaining Burbot were released into Boundary Creek. Zooplankton samples were collected from the Kootenai River, Boundary Creek, Deep Creek and the Goat River in the same manner as in 2012.

Burbot were measured to the nearest 0.5 mm (total length). Gape was measured to the nearest 0.001 mm using a gape micrometer (Arts and Evans 1987). A metal cone was inserted into the mouth of each Burbot until the mouth was fully extended (maximum gape). The cone diameter was measured at the point of full, natural extension of the mouth (Arts and Evans 1987; DeVries et al. 1998). Care was taken to avoid over-extending or otherwise distorting the mouth.

Following body measurements, Burbot were dissected and stomachs were excised. Stomachs were opened and contents were removed. All prey items were identified to the lowest possible taxon and enumerated. Taxa included *Bosmina* spp., Calanoida, *Ceriodaphnia* spp., *Chydorus* spp., Coleoptera, Cyclopoida, *Daphnia* spp., *Diaphanosoma* spp., Diptera, Ephemeroptera, Gastropoda, nauplii, Odonata, Ostracoda, *Polyphemus* spp. and Rotifera. In addition, up to 20 prey items from each taxon were measured along their longest axis to the nearest 0.001 mm using an ocular micrometer (Bremigan and Stein 1994; Garvey and Chipps 2012). For instance, *Daphnia* spp. were measured from the anterior portion of the carapace to the base of the posterior spine (DeVries et al. 1998). If prey items were partially digested, taxa were identified using diagnostic structures, but were not measured for total length. For example, partially digested dipterans were identified and enumerated using identifiable heads.

Zooplankton sampled from release locations were identified to the lowest possible taxon and enumerated. Two hundred to four hundred of the most abundant taxa were identified and enumerated to ensure the identification of rare taxa (DeVries et al. 1998; Bunnell et al. 2011). In addition, zooplankton were measured along their longest axis. Densities of all taxa in the environment were estimated as the total number of a given taxon sampled by the volume of water sampled. Analysis of Burbot diet and zooplankton data was conducted by year due to disparate sampling periods between years (May–July 2012; June–July 2013). In addition, prey use was not compared to prey availability because certain taxa (e.g., Diptera, Odonata, Coleoptera) were not effectively sampled with the Wisconsin-style plankton net. The ratio between maximum length of ingested prey and available prey was regressed against Burbot mouth gape to identify periods of potential gape limitation. Burbot with empty stomachs were removed from the analysis.

Results

Over the course of the study, 223 Burbot were sampled and 23 (12 in 2012; 11 in 2013) had empty stomachs. Burbot

growth differed between ponds in both years (Fig. 1). In pond 2, Burbot averaged about 66.0 mm of growth over 77 days; whereas, Burbot in pond 1 averaged approximately 44.0 mm of growth over the same time period. In 2013, Burbot in pond 2 averaged 16.0 mm of growth from June 14–July 10; whereas, Burbot in pond 1 averaged 10.5 mm of growth over the same period.

Temporal patterns in zooplankton density and assemblage were similar between ponds (Fig. 2). In May 2012, Cyclopoida and nauplii accounted for 53–64% of the zooplankton in each pond. The ponds were not sampled in May 2013; thus, comparisons across years were not possible. During both years, *Bosmina* spp. had the highest density in each pond and composed 37–79% of the zooplankton assemblage from June to July. Rotifera and cladocerans (e.g., *Ceriodaphnia* spp., *Daphnia* spp.) were nearly always present, but at relatively low densities. For example, at their highest density *Daphnia* spp. accounted for less

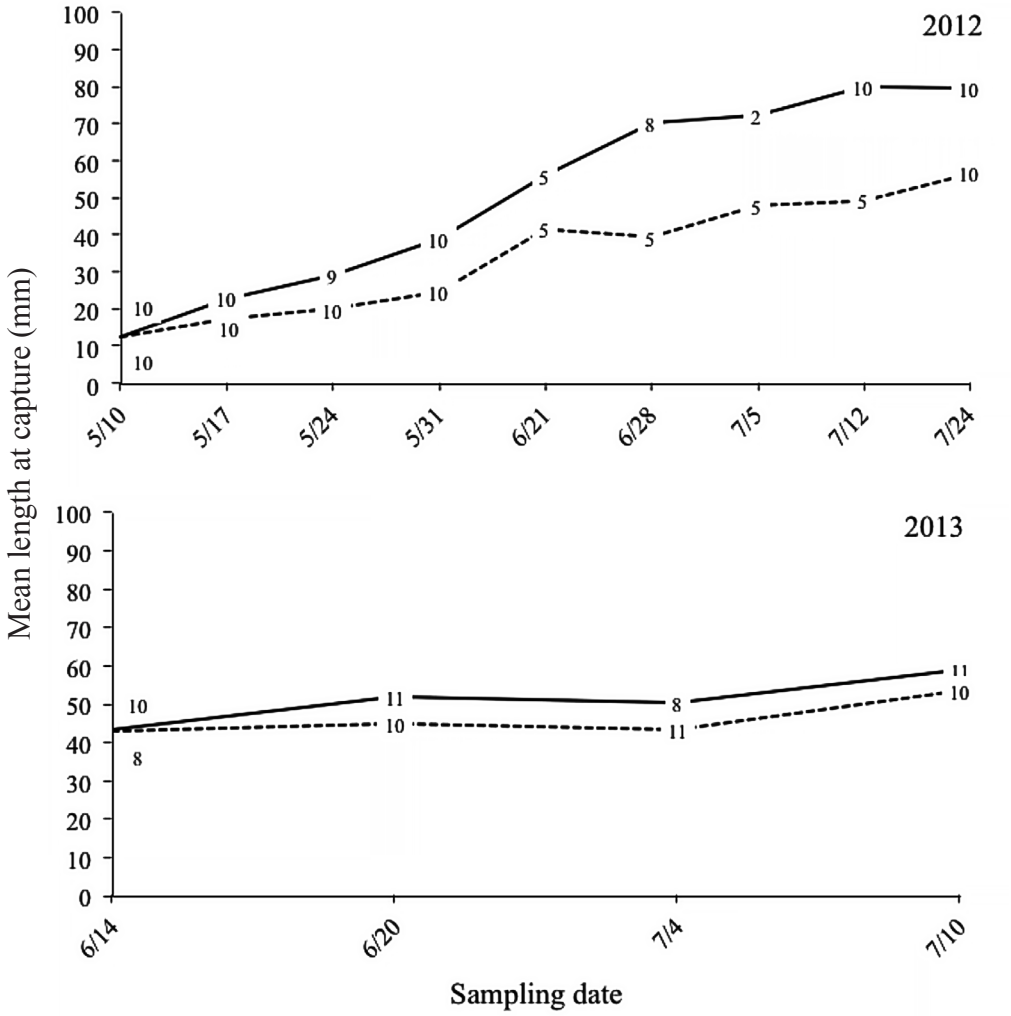

Figure 1. Mean length at capture for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho in 2012 and 2013. Dashed lines represent Burbot sampled from pond 1 and solid lines represent Burbot sampled from pond 2. Numbers along each line indicate the number of Burbot sampled on a given date.

than 5% of the total zooplankton (June 2012). Macroinvertebrates (e.g., Diptera, Coleoptera, Ephemeroptera) were poorly represented in zooplankton samples; but, this was likely due to sampling technique and not low densities.

Zooplankton at release locations showed similar patterns in zooplankton density and assemblage structure to the BCWMA ponds (Fig. 2). However, zooplankton densities were much lower among all release location than those observed in the BCWMA ponds. Boundary Creek had a mean density of approximately 30 zooplankton/L in 2012. *Bosmina* spp., *Daphnia* spp. and Cyclopoida were the most abundant zooplankton sampled in Boundary Creek in 2012 and represented 82% of the zooplankton present. Similarly, Cyclopoida and *Bosmina* spp. composed about 77% of the zooplankton present in the Kootenai River in 2012. Zooplankton densities were much lower across all release locations in 2013. The Kootenai River had the highest

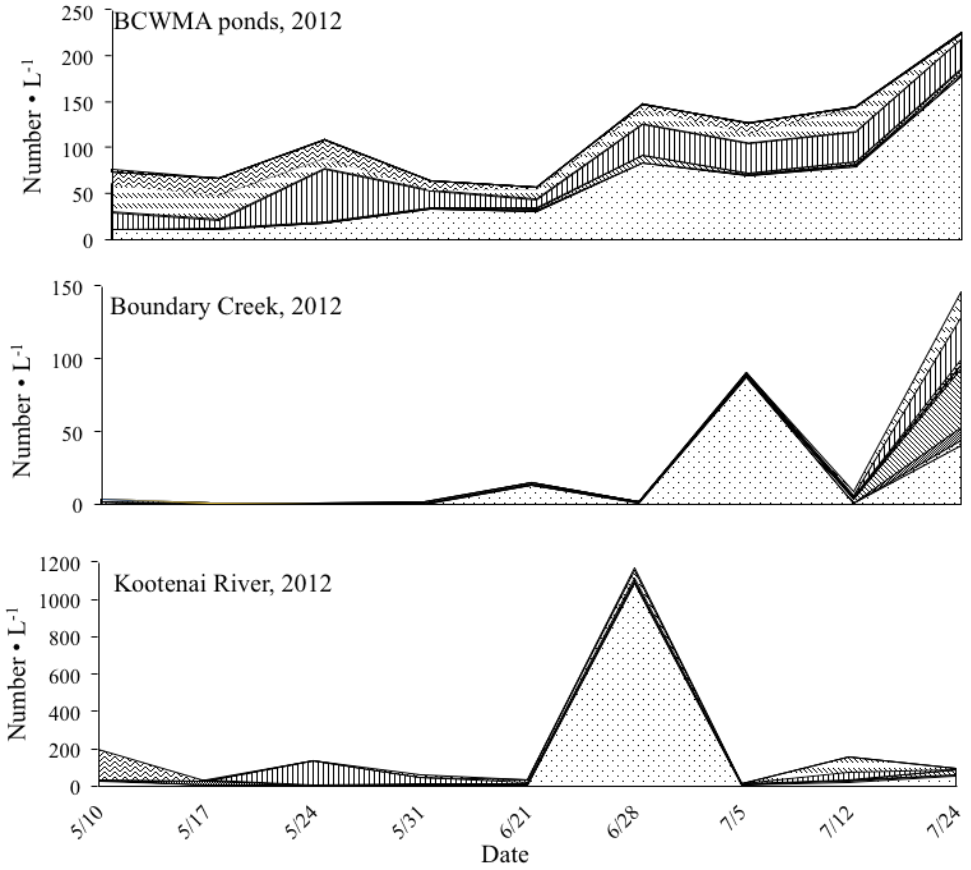

Figure 2. Zooplankton densities for Boundary Creek Wildlife Management Area ponds and stocking locations (i.e., Boundary Creek, Kootenai River, Goat River, Deep Creek). Prey categories include *Bosmina* spp. ( ), Calanoida ( ), *Ceriodaphnia* spp. ( ), *Chydorus* spp. ( ), Coleoptera ( ), Collembola ( ), Cyclopoida ( ), *Daphnia* spp. ( ), *Diaphanosoma* spp. ( ), Diptera ( ), Ephemeroptera ( ), Harpacticoida ( ), Hemiptera ( ), Hydrachnidae ( ), nauplii ( ), Ostracoda ( ), Plecoptera ( ), *Polyphemus* spp. ( ), Rotifera ( ), *Scapholeberis* spp. ( ).

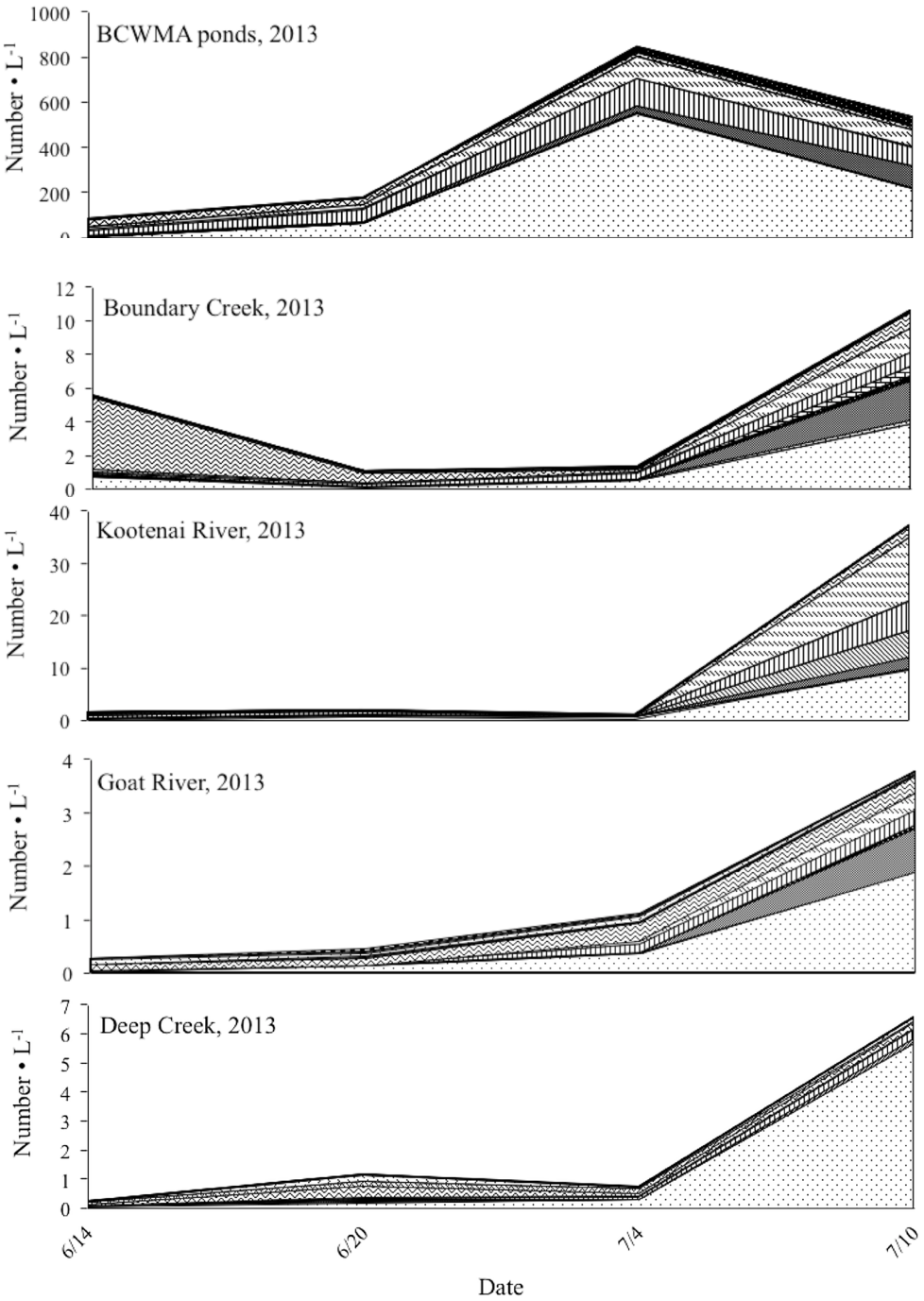

Figure 2. (continued) Zooplankton densities for Boundary Creek Wildlife Management Area ponds and stocking locations (i.e., Boundary Creek, Kootenai River, Goat River, Deep Creek). Prey categories include *Bosmina* spp. ( ), Calanoida ( ), *Ceriodaphnia* spp. ( ), Chydorus spp. ( ), Coleoptera ( ), Collembola ( ), Cyclopoida ( ), *Daphnia* spp. ( ), *Diaphanosoma* spp. ( ), Diptera ( ), Ephemeroptera ( ), Harpacticoida ( ), Hemiptera ( ), Hydrachnidae ( ), nauplii ( ), Ostracoda ( ), Plecoptera ( ), *Polyphemus* spp. ( ), Rotifera ( ), *Scapholeberis* spp. ( ).

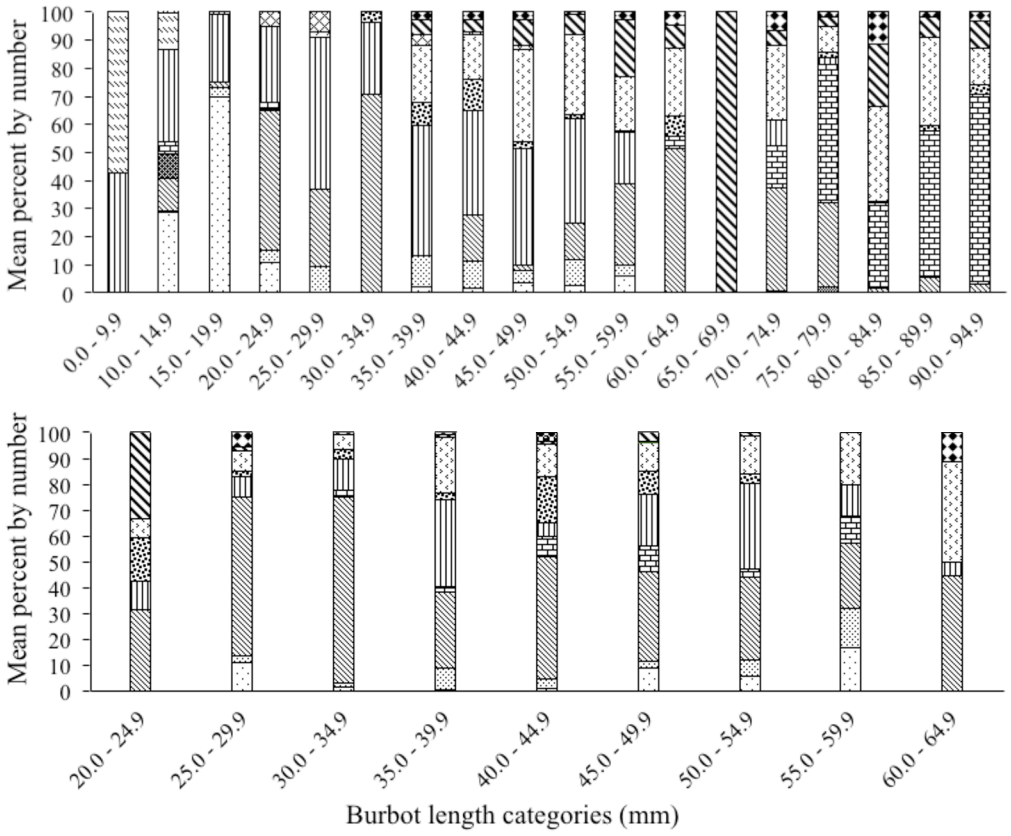

Figure 3. Diet composition by length category for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho. The top panel represents Burbot sampled in 2012 and the bottom panel represents Burbot collected in 2013. Prey categories include *Bosmina* spp. ( ), Calanoida ( ), *Ceriodaphnia* spp. ( ), *Chydorus* spp. ( ), Coleoptera ( ), Cyclopoida ( ), *Daphnia* spp. ( ), *Diaphanosoma* spp. ( ), Diptera ( ), Ephemeroptera ( ), Gastropoda ( ), nauplii ( ), Odonata ( ), Ostracoda ( ), *Polyphemus* spp. ( ) and Rotifera ( ).

density of all stocking locations (~10 zooplankton/L) in 2013. Larger zooplankton (e.g., Cyclopoida, *Daphnia* spp.) were poorly represented in 2013 with *Bosmina* spp. representing the highest densities across all sites.

Cyclopoida were common in the diet of juvenile Burbot (Fig. 3 and 4). At small sizes (<20.0 mm), juvenile Burbot predominantly fed on *Bosmina* spp., Cyclopoida and nauplii. *Bosmina* spp. and Cyclopoida accounted for 61% of the diet of 10.0–14.9 mm Burbot and 94% of the diet of 15.0–19.9 mm Burbot. Burbot greater than 20.0 mm consumed larger zooplankton such as *Daphnia* spp. However, Cyclopoida were always present in the stomachs of 20.0–59.9 mm Burbot and accounted for an average of 36% of their diet. Burbot greater than 59.9 mm had varied diets that were primarily composed of *Daphnia* spp., Calanoida and macroinvertebrates.

Mouth gape was positively related to Burbot length (Fig. 5) across both years. As mouth gape increased, the maximum length of ingested zooplankton remained

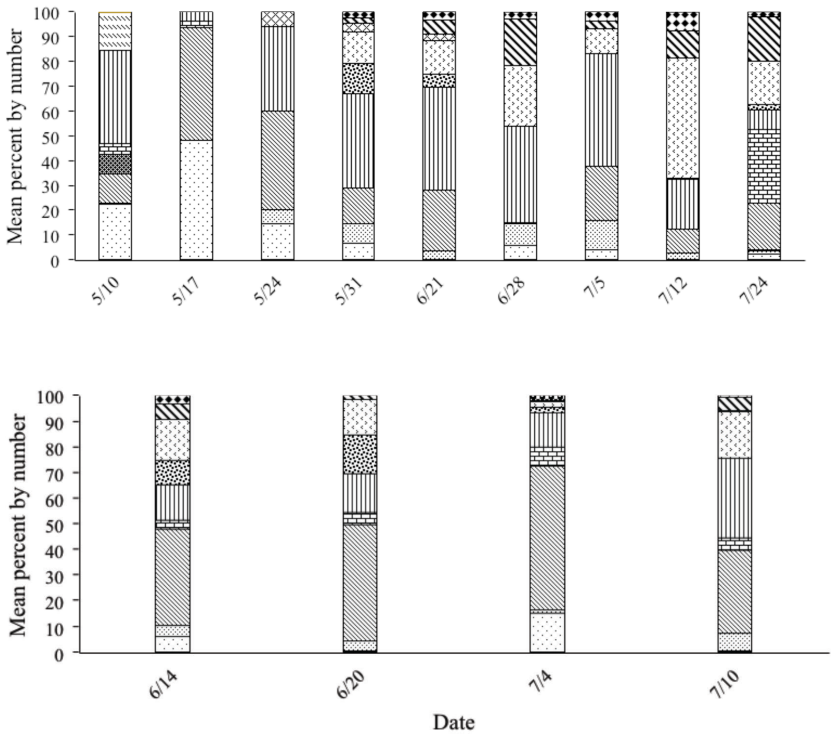

Figure 4. Mean percent by number of prey by date for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho. The top panel represents Burbot sampled in 2012 and the bottom panel represents Burbot collected in 2013. Prey categories include *Bosmina* spp. ( ), Calanoida ( ), *Ceriodaphnia* spp. ( ), *Chydorus* spp. ( ), Coleoptera ( ), Cyclopoida ( ), *Daphnia* spp. ( ), *Diaphanosoma* spp. ( ), Diptera ( ), Ephemeroptera ( ), Gastropoda ( ), nauplii ( ), Odonata ( ), Ostracoda ( ), *Polyphemus* spp. ( ) and Rotifera ( ).

relatively constant (Fig. 6). In 2012, mouth gape showed a weak, positive relationship with mean, minimum and maximum length of ingested zooplankton prey. Interestingly, mean and maximum length of ingested zooplankton were negatively related to mouth gape in 2013 (Fig. 6).

Across years, Burbot consumed the largest zooplankton available (Fig. 7). For instance, Burbot consumed zooplankton that were on average 50% larger than free-swimming zooplankton sampled in the BCWMA ponds in 2012. In 2013, Burbot consumed zooplankton that were on average 60% larger than free-swimming zooplankton sampled in the BCWMA ponds. Furthermore, mouth gape did not appear to influence the size of ingested zooplankton at any time during the study. For instance, Burbot with a gape less than 0.75 mm (SD = 0.06 mm) consumed zooplankton that averaged 1.12 mm (0.44 mm) in length. Burbot transitioned to macroinvertebrates when they reached approximately 60.0 mm in length, but measurement of macroinvertebrate prey was not possible due to partial digestion.

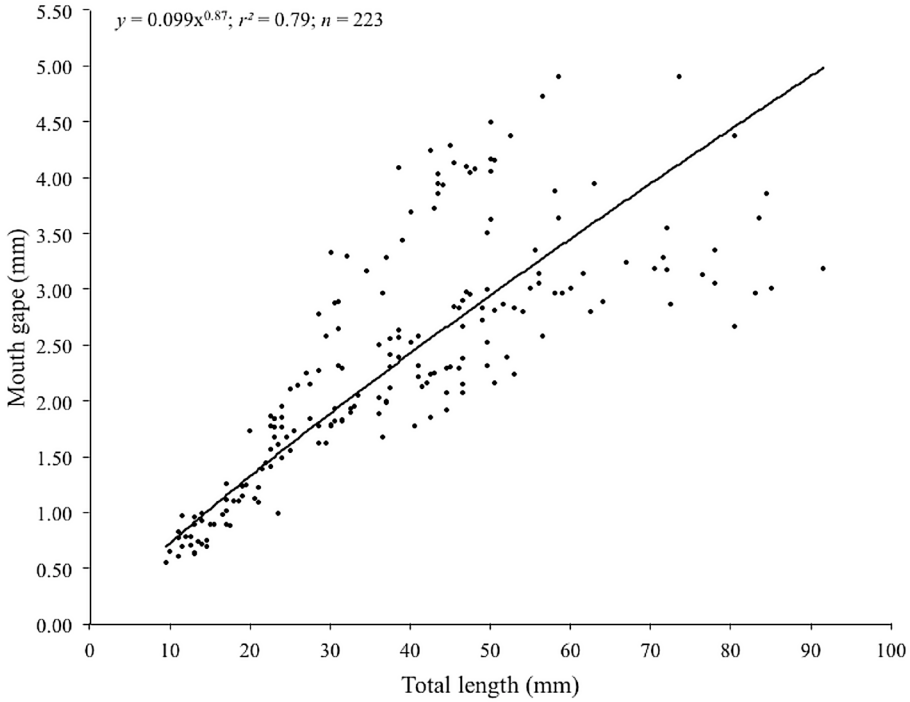

Figure 5. Mouth gape as a function of total length for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho in 2012 and 2013.

Discussion

The diet of juvenile Burbot in the BCWMA ponds was consistent with that reported in the literature. Ghan and Sprules (1993) evaluated diet of larval and juvenile Burbot in Oneida Lake, New York. Rotifera (*Asplanchna* sp.) and nauplii were the primary prey of 4.0–10.0 mm Burbot. Ten to fifteen millimeter Burbot predominantly fed on Cyclopoida and then transitioned to a greater diversity of prey items (*Daphnia* spp., Cyclopoida, Calanoida) after they reached 15.0 mm. In Lake Constance (Germany, Austria, Switzerland), 10.0 mm Burbot primarily fed on Cyclopoida and nauplii (Probst and Eckmann 2009). Thereafter, Cyclopoida accounted for about 40% of Burbot diet. George et al. (2013) reported that juvenile Burbot in Lake Huron, Michigan fed almost exclusively on copepods. Furthermore, Cyclopoida were the dominant prey item and accounted for 43% of Burbot diet from April–July. Cyclopoida accounted for about 30% of the diet of Burbot from May–July in the current study. Although juvenile Burbot appear to select for Cyclopoida, it is unclear which factors (e.g., prey size, spatial overlap) contribute to prey choice in juvenile Burbot.

Maximum gape is often considered to be a principal feature contributing to prey choice in juvenile fishes (Mills et al. 1984; Miller et al. 1988; Schael et al. 1991). Fish typically consume progressively larger prey items as gape increases (O'Brien 1979; O'Brien 1987; Schael et al. 1991). In the current study, Burbot did not show a strong relationship between gape and prey size as has been reported for other fishes. In fact, Burbot in the BCWMA ponds never appeared to be gape limited for zooplankton and consistently ate similarly sized zooplankton. For example, Burbot in BCWMA ponds regularly ate

zooplankton with lengths that exceeded their maximum mouth gape when gape was between 0.5–2.0 mm. Once mouth gape was greater than 2.0 mm, Burbot continued to eat zooplankton that were similar in length to those consumed at smaller gape sizes. Ghan and Sprules (1993) reported similar findings in regard to maximum gape and prey length. For example, Burbot in Oneida Lake with mouth gapes between 0.25–2.0

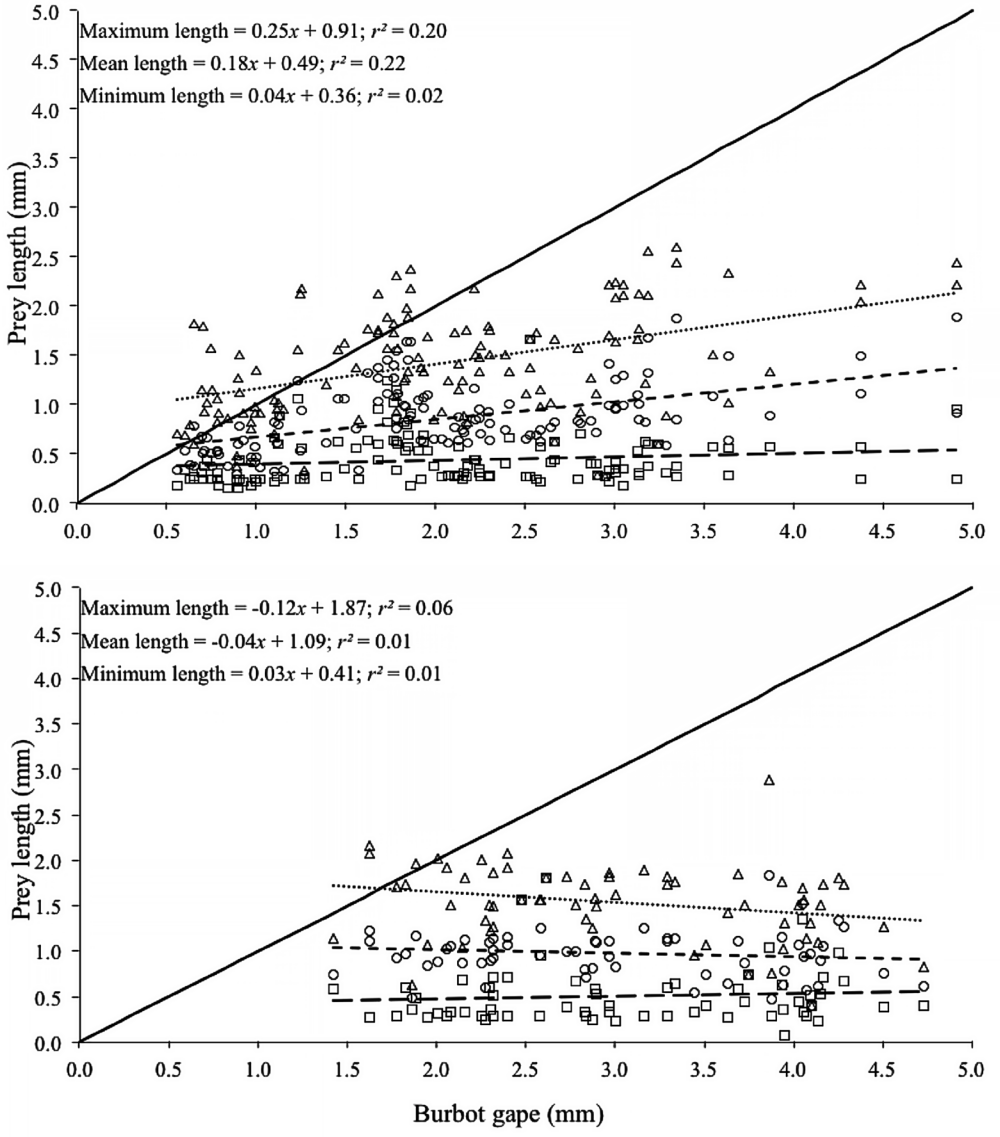

Figure 6. Length of ingested prey versus mouth gape for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho in 2012 and 2013. Stomach contents are represented as the mean (open circle), maximum (open triangle) and minimum (open square) length of prey found in each Burbot stomach (n = 200). Regression equations for maximum (dotted line), mean (dashed line) and minimum (long-dashed line) ingested prey length are presented. Solid lines denote mouth gape equal to ingested prey length. The top panel represents Burbot sampled in 2012 and the bottom panel represents Burbot sampled in 2013.

mm often consumed prey items with lengths greater than maximum mouth gape (Ghan and Sprules 1993). However, the authors noted that prey width rather than prey length limited the size of prey ingested by larval and juvenile Burbot. When mouth gape was less than 0.35 mm, the width of ingested prey approached or equaled gape. Once maximum gape exceeded 0.75 mm, Burbot consumed prey with widths considerably smaller than their maximum gape (Ghan and Sprules 1993). Prey width was not measured in the current study; however, the work conducted by Ghan and Sprules (1993) suggests that Burbot are briefly gape limited during early development. Although prey choice appears to be partly dictated by gape, it remains unclear why Burbot select specific

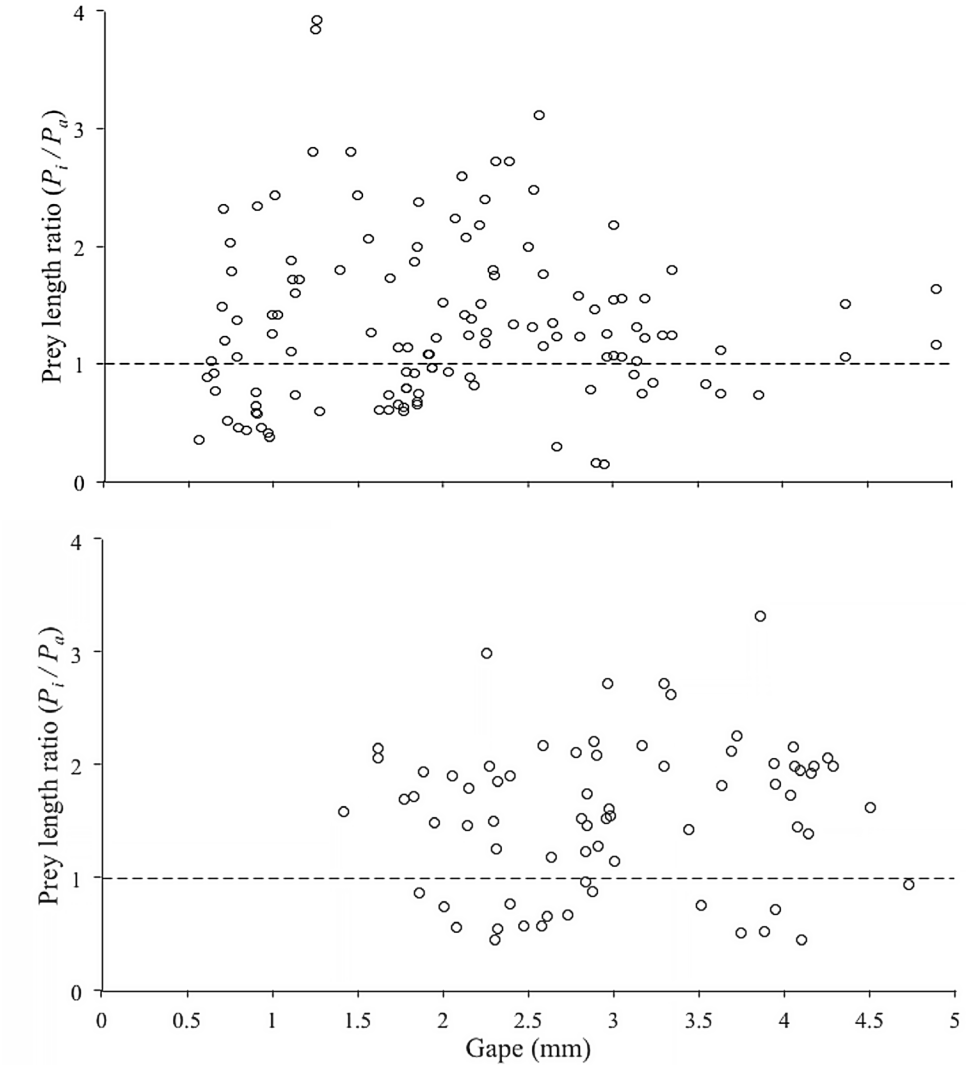

Figure 7. Ratio of maximum length of ingested prey (Pi) and available prey (Pa) versus gape for Burbot sampled from the Boundary Creek Wildlife Management Area ponds, Bonners Ferry, Idaho. The top panel represents Burbot sampled in 2012 and the bottom panel represents Burbot sampled in 2013. Dashed lines denote maximum length of ingested prey equal to maximum length of prey available in each pond.

prey taxa (copepods) over other, similarly sized prey items (daphnids).

The type of prey juvenile fish ingest can be determined by capture efficiency and handling time (Werner and Hall 1974; O'Brien et al. 1976; Gill 2003). Capture efficiency represents the success rate of capturing prey items (Gill 2003); whereas, handling time reflects the amount of time required to capture and swallow prey items (Sreekumari and Aravindan 1993). Intuitively, fish should maximize capture efficiency while reducing handling time (O'Brien 1979). Copepods generally have lower capture probabilities than cladocerans due to their quick, erratic movements (Drenner et al. 1980). Ghan and Sprules (1993) suggested that Cyclopoida are more visible to larval Burbot due to their irregular, darting movements. Additionally, George et al. (2013) posited that copepods are more visible than cladocerans because of their dark pigmentation. Burbot are visual feeders (Wocher et al. 2011) that exhibit crepuscular foraging behavior (Martin et al. 2011). Thus, fast moving, highly visible prey may be more readily identified and consumed than slow moving, lightly pigmented prey (e.g., *Daphnia* spp.). Regardless, Cyclopoida appear to be an important prey resource for larval and juvenile Burbot.

The impetus for the current study was that low prey availability was contributing to poor recruitment of Burbot in the Kootenai River. From 2009–2015, over 1,500,000 age-2 and younger Burbot were stocked into the Kootenai River and its tributaries. Of these, 1,328,538 Burbot were less than 60 days post hatch which roughly corresponds to a mean maximum length of 9.0 mm. Small Burbot (10.0–20.0 mm) predominantly fed on Cylopoida and *Bosmina* spp. in the current study. If Burbot stocked into the Kootenai River and its tributaries exhibit similar feeding habits, the majority of Burbot released will likely require high densities of zooplankton to avoid starvation. Unfortunately, identifying what constitutes a "high density" of zooplankton is difficult due to the paucity of data surrounding the food requirements of Burbot. Therefore, future research is needed to understand if current release locations support zooplankton densities sufficient to support larval and juvenile Burbot. Managers could also focus on releasing larger Burbot that do not require zooplankton prey. Our results indicate that Burbot transition from zooplankton prey to macroinvertebrates around 60.0 mm. A similar shift from zooplankton to macroinvertebrates has been reported in other studies. For instance, Ryder and Pesendorfer (1992) found that approximately 80% of the diet of 41.0–114.0 mm Burbot was composed of Amphipoda. Similarly, juvenile Burbot (51.0–102.0 mm) in the White River, Michigan primarily fed on Amphipoda and Ephemeroptera (Beeton 1956). If Burbot were stocked at larger lengths, they may benefit from abundant prey that has not been appropriately quantified in this and other studies. Regardless of the chosen release strategy, the identification of stocking locations with relatively high densities of high quality prey is necessary to ensure the rehabilitation of Burbot in the Kootenai River.

Acknowledgments

We thank K. McBaine and M. Thomas for assistance with processing samples in the laboratory. We thank S. Young, C. Laude and J. Hughes for their help with Burbot stocking and sample collection. We also thank the University of Idaho's Aquaculture Research Institute for their support with intensive culture of Burbot. We thank J. Walrath and two anonymous reviewers who provided helpful comments on a previous version of the manuscript. Funding for the project was provided by Idaho Department of Fish and Game. Additional support was provided by the U.S. Geological Survey, Idaho Cooperative Fish and Wildlife Research Unit. The Unit is jointly sponsored by the U.S. Geological Survey, University of Idaho and Idaho Department of Fish and Game and Wildlife Management Institute. This project was conducted under the University of Idaho Institutional Animal

Care and Use Committee Protocol 2011-33. The use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Literature cited

Anderson, J. T. 1988. A review of size dependent survival during pre-recruit stages of fishes in relation to recruitment. Journal of Northwest Atlantic Fisheries Science 8:55–66.

Arndt, S. and J. Hutchinson. 2000. Characteristics of a tributary-spawning population of burbot from Columbia Lake. Pages 48–60 *in* V. L. Paragamian and D. W. Willis, editors. Burbot biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication 1, Bethesda, MD.

Arts, M. T. and D. O. Evans. 1987. Precision micrometer measurement of mouth gape of larval fish. Canadian Journal of Fisheries and Aquatic Sciences 44:1786–1791.

Bunnell, D. B., B. M. Davis, D. M. Warner, M. A. Chriscinske and E. F. Roseman. 2011. Planktivory in the changing Lake Huron zooplankton community: Bythotrephes consumption exceeds that of *Mysis* and fish. Freshwater Biology 56:1281–1296.

Beeton, A. M. 1956. Food habits of the Burbot (*Lota lota lacustris*) in the White River, a Michigan trout stream. Copeia 1:58–60.

Bremigan, M. T. and R. A. Stein. 1994. Gape-dependent larval foraging and zooplankton size: implications for fish recruitment across systems. Canadian Journal of Fisheries and Aquatic Sciences 51:913–922.

Crowder, L. B., M. E. McDonald and J. A. Rice. 1987. Understanding recruitment of Lake Michigan fishes: the importance of size-based interactions between fish and zooplankton. Canadian Journal of Fisheries and Aquatic Sciences 44:141–147.

Cushing, D. H. 1969. The regularity of the spawning season of some fishes. Journal du Conseil International pour l'Exploration de la Mer 33:81–92.

Cushing, D. H. 1990. Plankton production and year-class strength in fish populations: an update of the match/mismatch hypothesis. Advances in Marine Biology 26:249–293.

DeVeries, D. R., M. T. Bremigan and R. A. Stein. 1998. Prey selection by larval fishes as influenced by the available zooplankton and gape limitation. Transactions of the American Fisheries Society 127:1040–1050.

Drenner, R. W. and S. R. McComas. 1980. The roles of zooplankton escape ability and fish size selectivity in the selective feeding and impact of planktivorous fish. Pages 587–593 *in* W. C. Kerfoot, editor. Evolution and ecology of zooplankton communities. University Press of New England, Hanover.

Dixon, C. J. and J. C. Vokoun. 2010. Population structure and diet of burbot (*Lota lota*) in small streams near the southern extent of the species' range. Journal of Freshwater Ecology 25:49–58.

Garvey, J. E. and S. R. Chipps. 2012. Diet and energy flow. Pages 733–779 *in* A. V. Zale, D. L. Parrish and T. M. Sutton, editors. Fisheries techniques, 3rd edition. American Fisheries Society, Bethesda, Maryland.

George, E. M., E. F. Roseman, B. M. Davis and T. P. O'Brien. 2013. Feeding ecology of pelagic larval Burbot in northern Lake Huron, Michigan. Transactions of the American Fisheries Society 142:1716–1723.

Graeb, B. D. S., J. M. Dettmers, D. W. Wahl and C. E. Cáceres. 2004. Fish size and prey availability affect growth, survival, prey selection and foraging behavior of larval Yellow Perch. Transaction of the American Fisheries Society 133:504–514.

Ghan, D. and W. G. Sprules. 1993. Diet, prey selection and growth of larval and juvenile Burbot *Lota lota* (L.). Journal of Fish Biology 42:47–64.

Gill, A. B. 2003. The dynamic of prey choice in fish: the importance of prey size and satiation. Journal of Fish Biology 63:105–116.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe, viewed in the light of biological research. Rapports et Procès Verbaux des Réunions du Conseil International pour l'Exploration de la Mer 20:1–228.

Howes, G. J. 1991. Biogeography of gadoid fishes. Journal of Biogeography 18:595–622.

IDEQ (Idaho Department of Environmental Quality). 2006. Assessment of water quality in Kootenai River and Moyie river subbasins (TMDL). Idaho Department of Environmental Quality, Couer d'Alene Regional Office, Coeur d'Alene, Idaho.

Jensen, N. R., S. C. Ireland, J. T. Siple, S. R. Williams and K. D. Cain. 2008. Evaluation of egg incubation methods and larval feeding regimes for North American Burbot. North American Journal of Aquaculture 70:162–170.

Knudson, K. 1994. Water quality status report: Kootenay (Kootenai) River Basin, British Columbia, Montana and Idaho. The Kootenai River Network, Libby, MT. and Ecological Resource Consulting, Helena, Montana.

KVRI (Kootenai Valley Resource Initiative) Burbot Committee. 2005. Kootenai River/Kootenay Lake Burbot conservation strategy. Kootenai Tribe of Idaho, Bonners Ferry.

Martin, B., S. Czesny and D. Wahl. 2011. Vertical distributions of larval fish in pelagic waters of southwest Lake Michigan: implications for growth, survival and dispersal. Journal of Great Lakes Research 37:279–288.

Miller, T. L., L. B. Crowder, J. A. Rice and E. A. Marschall. 1988. Larval size and recruitment mechanisms in fishes: toward a conceptual framework. Canadian Journal of Fisheries and Aquatic Sciences 45:1657–1670.

Mills, E. L., J. L. Confer and R. C. Ready. 1984. Prey selection by young yellow perch: the influence of capture success, visual acuity and prey choice. Transactions of the American Fisheries Society 113:579–587.

Neufeld M. D. and C. R. Spence. 2004. Evaluation of a simple decompression procedure to reduce decompression trauma in trap-caught Burbot. Transactions of the American Fisheries Society 5:1260–1263.

O'Brien W. J. 1979. The predator-prey interaction of planktivorous fish and zooplankton: recent research with plantivorous fish and their zooplankton prey shows the evolutionary thrust and parry of the predator-prey relationship. American Scientist 67:572–581.

O'Brien, W. J. 1987. Planktivory by freshwater fish: thrust and parry in the pelagia. Pages 3–16 *in* W. C. Kerfoot and A. Sih, editors. Predation, University Press of New England, Hanover.

Paragamian, V. L. 2000. The effects of variable discharges on burbot spawning migrations in the Kootenai River, Idaho, USA and British Columbia, Canada. Pages 111–123 *in* V. L. Paragamian and D. W. Willis, editors. Burbot biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication 1, Bethesda, Maryland.

Paragamian, V. L. and V. D. Wakkinen. 2008. Seasonal movement of Burbot in relation to temperature and discharge in the Kootenai River, Idaho, USA and British Columbia, Canada. American Fisheries Society Symposium 59:55–77.

Paragamian, V. L. and M. J. Hansen. 2009. Rehabilitation need for Burbot in the Kootenai River, Idaho, USA and British Columbia, Canada. North American Journal of Fisheries Management 29:768–777.

Probst, W. N. and R. Eckmann. 2009. Diet overlap between young-of-the-year perch *Perca fluviatilis* (L.) and burbot, *Lota lota* (l.), during earl life-history stages. Ecology of Freshwater Fish 18:527–537.

Ryder, R. A. and J. Pesendorfer. 1992. Food, growth, habitat and community interactions of young-of-the-year burbot, *Lota lota* L., in a Precambrian Shield Lake. Hydrobiologia 243:211–227.

Schael, D. M., L. G. Rudstam and J. R. Post. 1991. Gape limitation and prey selection in larval yellow perch (*Perca flavescens*), freshwater drum (*Aplodinotus grunniens*) and black crappie (*Pomoxis nigromaculatus*). Canadian Journal of Fisheries and Aquatic Sciences 48:1919–1925.

Sreekumari, T. and C. M. Aravindan. 1993. Influence of size, station time and satiation amount on the prey handling time in *Anabas testudineus* (Bloch). Journal of Indian Fisheries Association 23:105–108.

Spence, C. R. 2000. A comparison of catch success between two styles of burbot traps in lakes. Pages 165–170 *in* V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology and management. American Fisheries Society, Fisheries Management Section, Publication 1, Bethesda, Maryland.

Werner, E. E. and D. J. Hall. 1974. Optimal foraging and the size selection of prey by bluegill sunfish (*Lepomis macrochirus*). Ecology 55:1042–1052.

Wocher, H., A. Harsányi and F. J. Schwarz. 2011. Larviculture of Burbot (*Lota lota* L.): larval rearing using *Artemia* and Weaning onto dry feed. Aquaculture Research 44:106–113.

Received 05 August 2016
Accepted 21 November 2016

Fish Assemblage Structure and Growth in the Lower Milk River, Montana in Relation to Environmental Conditions

Marc M. Terrazas[1], Department of Fish and Wildlife Sciences, University of Idaho, MS1136, Moscow, Idaho 83844-1136

Julie Bednarski[2], Department of Fish and Wildlife Sciences, University of Idaho, MS1136, Moscow, Idaho 83844-1136

Dennis L. Scarnecchia[*], Department of Fish and Wildlife Sciences, University of Idaho, MS1136, Moscow, Idaho 83844-1136

Abstract

With the major habitat alterations on the Missouri River in the 20th century, native fishes must rely more heavily on the larger, more natural, inflowing tributaries for spawning and rearing habitat. A two-year study was conducted to investigate the occurrence and abundance of fishes in the lower Milk River, Montana, which enters the Missouri River immediately below Fort Peck Dam. In sampling conducted from May to August in successive years (2002, 2003), the fish species assemblage included multiple species of special concern (blue sucker *Cycleptus elongatus*, paddlefish *Polydon spathula*, sauger *Sander canadense*) and multiple watch list species identified by the Montana Natural Heritage Program (burbot *Lota lota*, brassy minnow *Hybognathus hankinsoni*, plains minnow *Hybognathus placitus*). Relationships with environmental conditions and their interactions with temporal variables (month, year) were investigated for occurrence and total catch data. Models were generally similar for individual species with temperature and turbidity being the primary environmental conditions influencing fish occurrence and abundance. Age and growth analysis was conducted on channel catfish (*Ictalurus punctatus*), sauger, walleye (*Sander vitreus*), northern pike (*Esox lucius*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*). Channel catfish, sauger, walleye and shovelnose sturgeon all grew slower and lived longer in the lower Milk River than populations at lower latitudes. In view of the lower Milk River's role as spawning and rearing habitat for native fishes and its history of alterations from upriver dams and irrigation withdrawals, more attention should be given to maintaining or improving existing habitat conditions, including adequate instream flows and turbidity.

Key words: Milk River, Missouri River, native species, environmental conditions, spawning, von Bertalanffy

Introduction

In the past century, large rivers worldwide have undergone extensive modifications, including damming, channelization and diversion, as part of diverse human development along watercourses (Hynes 1989). As flowing water habitats in main-stem rivers have undergone impoundment, hydrograph and temperature changes and suspended sediment reductions, major inflowing tributaries have assumed greater importance for providing the remaining spawning and rearing habitat for many native fishes formerly dominant in and reliant upon, large rivers (Benda et al. 2004; Moyle and Mount 2007).

On the upper Missouri River, major habitat changes over the past century, especially the construction of Fort Peck Dam, have greatly altered habitats for native

*Corresponding author: scar@uidaho.edu
[1] Current address: PO Box 503, Thompson Falls, MT 59873
[2]Current address: PO Box 10024, Douglass, AK 99811

fish species. Remnant habitat in tributaries such as the lower Milk River, which enters the Missouri River immediately below the dam, may assume much greater, or even critical, importance in species survival. The Milk River below its lowermost dam (Vandalia Dam, 188 rkm) has well-developed riparian zones, cobble riffles and an incised channel (Stash et al. 2001). That portion of the river provides a diversity of habitats used by several native fish species both common and of conservation concern in the Missouri River drainage. Stash et al. (2001) observed that three migratory species from the Missouri River, blue sucker (*Cycleptus elongatus*), shovelnose sturgeon (*Scaphirhynchus platorynchus*) and paddlefish (*Polyodon spathula*) were found in the Milk River below Vandalia Dam. Seven other native fish species, bigmouth buffalo (*Ictiobus cyprinellus*), channel catfish (*Ictalurus punctatus*), freshwater drum (*Aplodinotus grunniens*), goldeye (*Hiodon alosoides*), river carpsucker (*Carpiodes carpio*), shorthead redhorse (*Moxostoma macrolepidotum*) and smallmouth buffalo (*Ictiobus bubalus*) were captured in the lowermost 400 km of the Milk River (Stash et al. 2001). Most fish were captured below Vandalia Dam, which may indicate that the fish above the dam are isolated from fishes below the dam, which are mainly migratory fish from the Missouri River (Stash et al. 2001). These and other fishes may be relying more heavily on the lower Milk River for spawning and rearing habitat than prior to Missouri River alteration.

In years with high spring flows, the Milk River functions much like a natural, undammed river in terms of a range of physical habitat features, including depth, velocity, turbidity and temperature. The warm, turbid character of the lower Milk River differs sharply and abruptly from conditions in the Missouri River at their confluence. Downstream of Fort Peck Dam, the Missouri River is cold (15°C, July) and clear (10 nephelometric turbidity units (NTU), July), as a result of hypolimnetic discharge from Fort Peck Dam and sediment trapping by the reservoir. In contrast, the Milk River retains some of the characteristics of the Missouri River prior to alteration; it is warmer (30°C, July), more turbid (1000 NTU, July) and less altered.

However, in the past century the Milk River has experienced a 60 percent decrease in the magnitude of the two-year flood and similar decreases in larger, less frequent flood events (Shields et al. 2000) as a result of seven impoundments. The impoundments extend from 188 km to 699 km upstream of the confluence with the Missouri River and have been developed mainly for irrigation. The dams have resulted in a reduction in high spring flows and have created barriers to fish movement. Such alterations may affect the spawning and rearing ability of the resident fish, as well as native migratory fish from the Missouri River, especially if the Missouri River fish rely on the seasonal flows of the Milk River for spawning.

As part of a broader interest in maintaining habitats for native species in the Missouri River, background information was needed on the fish of the lower Milk River as those fish may contribute to survival of main-stem Missouri River native fish fauna. This study was designed to provide information on the fish fauna of the lower river. The objectives of this study were to 1) evaluate occurrence, abundance (total catch), species richness and fish assemblage structure among sampling sites in relation to environmental conditions potentially influencing fish presence and abundance; and 2) evaluate age and growth of important recreational fishes in relation to adjacent populations of fish.

Study area

Lewis and Clark named the Milk River, one of the largest tributaries to the upper Missouri River, for its milky-colored, turbid waters. The Milk River main-stem is 1,126 river kilometers (rkm) in length and drains an area of approximately 59,857 km^2 (Milk River Watershed Council Canada 2013). From the headwaters in Glacier National Park, Montana, the Milk River flows northeast, crossing into Canada for

approximately 275 km (Stash et al. 2001). The river re-enters the United States in Hill County, Montana and flows through most of the north central portion of the state to its confluence with the Missouri River immediately downstream of Fort Peck Dam (Fig. 1).

Continental glaciers from the Quarternary Period have greatly influenced the topography of the lower Milk River basin as it exists today. The advance and recession of the continental glaciers left deposits of ground and terminal moraines and outwash channel deposits (Alden 1932). Sand, silt and clay of recent alluvial deposits thinly cover older glacial deposits along the alluvium of the Milk River (Montana Department of Health and Environmental Sciences 1974).

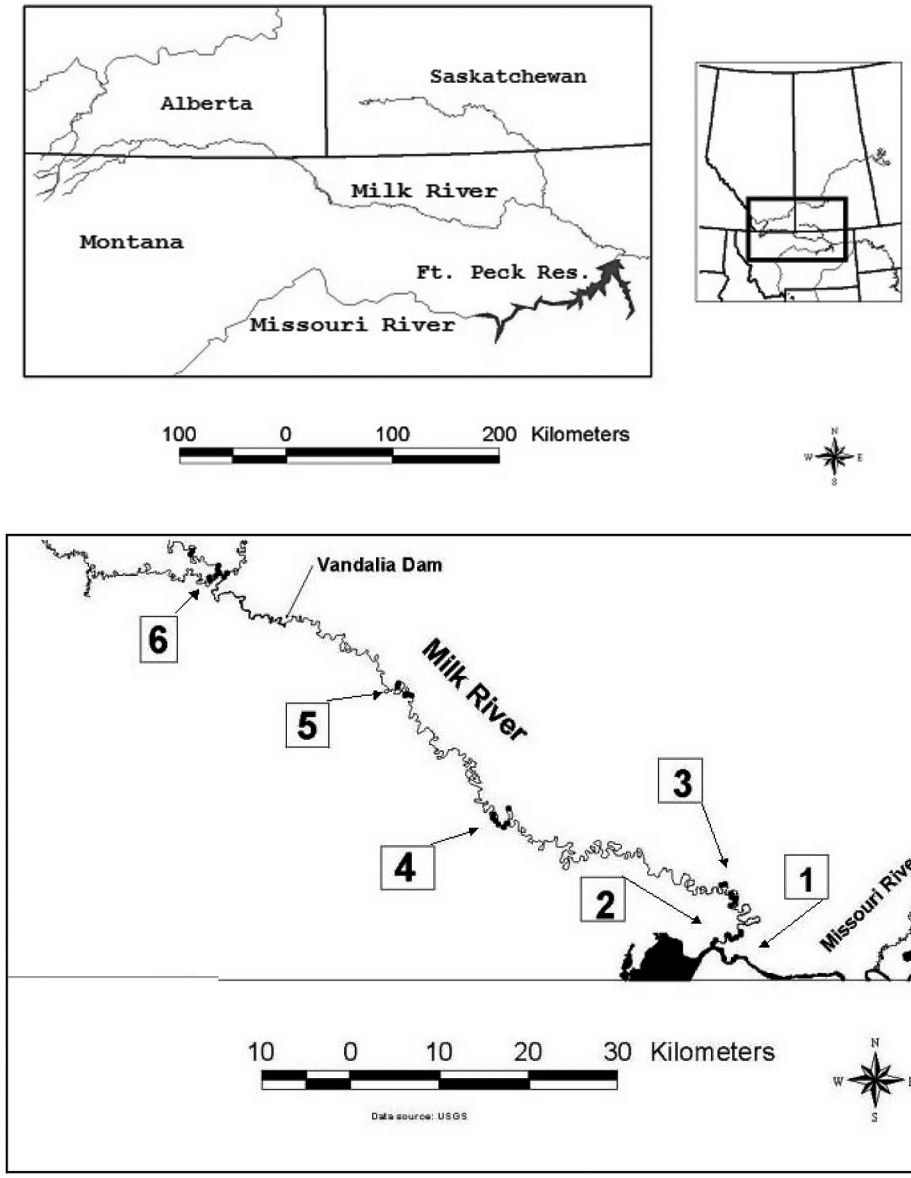

Figure 1. Map of the lower Milk River study area showing the specific sampling locations.

In the past century, the Milk River has become an important source of irrigation and municipal water. Approximately 558 km^2 of land are irrigated from the river, primarily for alfalfa, native hay, oats, wheat and barley (United States Bureau of Reclamation 1983; Simonds 1998). Twelve municipalities rely on water from the river for drinking water and sewage systems. Most of the irrigation water comes from the Milk River Project, one of the first U.S. Bureau of Reclamation irrigation projects, developed in 1902 (Simonds 1998). This project diverts and stores water with three storage dams, four diversion dams (one in our study area) and a pumping plant (Montana Department of Natural Resources and Conservation 1990).

The portion of the Milk River included in the study extends from the confluence of the Milk River with the Missouri River, to 20 rkm above Vandalia Dam, the first major diversion dam (Fig. 1). The first 4.8 rkm of the Missouri River downstream of the Milk River were also included in the study area, making a total study area of 212.8 rkm. The lower Milk River has been previously identified as having a warmwater and coolwater fish species assemblage (Stash et al. 2001).

Methods

Fish Collection

Sampling was conducted in two years, 2002 (Year 1) and 2003 (Year 2) at locations along the entire study area. Riffle and run habitats within the study area were sampled. Riffles were classified as areas with shallow, turbulent water passing through or over cobble or gravel of a fairly uniform area. Runs were classified as areas with a depth of at least 0.9 m with slow to moderate current. Areas of slower moving water, pool-like in nature, were classified as pools. Five sampling locations were established on the Milk River and one sampling location was established on the Missouri River. At each location, three random sampling sites were established.

Sites were repeatedly sampled with five gears: sinking gill nets, floating gill nets, trammel nets, hoop nets and bag seines, to increase the probability of sampling species present in each location. Each gear was deployed at least three times per site on the lower Milk River from mid-May to mid-August in both sampling years. Stationary gill nets and hoop nets were set overnight. Stationary sinking gill nets were 30 m long by 1.8 m high and were divided into four equal panels of 1.9 cm, 3.8 cm, 5 cm and 7.6 cm bar measure mesh. Floating gill nets were 150 m in length, by 1.8 m high, with 7.6 cm bar measure mesh. Trammel nets were 22.9 m in length with a 2.5 cm inner mesh and a 15.2 cm outer mesh. Hoop nets were 1 m in diameter with 2.5 cm bar measure mesh. Bag seines were of two sizes: 10.7 m long by 1.8 m tall and 7.6 m long by 1.8 m tall. Both seines had a 1.8m x 1.8m base at the center of the net with a 5 mm ace mesh and a “many ends” mud lead line attached.

Most fish were identified to species in the field except members of the genus *Hybognathus* which were grouped and recorded together. Fish were weighed (g) and total length was recorded (mm) for all species, except sturgeon, where fork length was used and paddlefish, where body length from eye to fork of caudal fin was used (Ruelle and Hudson 1977). Relative weights (*Wr*) were calculated for the common recreational game fish. Fulton's condition factor (*K*; Ricker 1975) was calculated as an additional metric of condition and was the only condition metric for two species with no standard weight (W_s) equation. The presence of mature fish with milt or roe was sought as evidence of spawning activity. Sampled fish were checked manually; if roe or milt was detected after gentle pressure was applied to the abdomen, the fish was recorded as gravid.

We did not attempt to calibrate for gear differences in catchability by species, although we knew they existed. We compared total catches to assess abundance of fish consolidated across sampling gears.

We were, however, interested in assessing the influence of abiotic factors on fish use and total catch. Occurrence and abundance for each species was analyzed using environmental conditions as covariates in multiple regression models.

Turbidity at each site was measured in NTU's using a Hach model 2100P (Hach Corp., Loveland, CO). Depth and temperature were also measured during sampling. Daily discharge measurements were available from the U.S. Geological Service gauging stations (06174500; 06172310) on the Milk River near Nashua and Tampico Road, Montana. Flows were averaged for the sampling day and two days prior under the assumption that current stream flow may be only partially causative of species presence and a recent average stream flow would potentially provide more information on conditions fish cue on in a sampling location.

Age and Growth

Hard structures were collected for age and growth analysis for five common recreational fish species: channel catfish, walleye (*Sander vitreus*), shovelnose sturgeon, sauger (*Sander canadensis*) and northern pike (*Esox lucius*). The structures selected for use in age determination were based on previous studies documenting the utility of a particular structure. Random samples of pectoral fin rays were collected from channel catfish (Starkey and Scarnecchia 1999) with lengths ≥ 300 mm. Lead pelvic and dorsal fin rays were collected from all sauger and walleye (Borkholder and Edwards 2001). Cleithra were opportunistically collected from all incidental mortalities of northern pike (Casselman 1974). Pectoral fin rays were collected from shovelnose sturgeon (Everett et al. 2003; Koch et al. 2008).

The methods for determining the age from fin rays followed DeVries and Frie (1996) as modified in the lab according to Dingman (2001). The fin rays were glued parallel to a labeled, wooden stick using clear epoxy with the end nearest point of articulation closest to end of the stick. The glued fin rays were allowed to dry for 24 hours before cutting.

The fin ray sections were cut with a low speed saw (Buehler, Lake Bluff, IL) equipped with a 10 cm diameter by 0.3 mm thick diamond-edge blade. The first cut was made as close to the end of the fin rays as possible to create a smooth edge. Each additional cut resulting in a thin section was viewed under a microscope attached to an Optical Pattern Recognition System (OPRS; BioSonics Inc., Seattle, WA) to determine if adjustments needed to be made during the cutting process to improve the resolution of the section. Whole cleithra or four fin ray sections were placed on a glass slide using clear fingernail polish and viewed under the OPRS.

Annuli were enumerated to determine age. No validation of age was possible, each ring was assumed to be an annulus. If the sections were not readable a second series of cuts was attempted. Two people (a primary and secondary reader) independently aged sections from each fish. If the disagreement for fish aged between 5 to 10 were within one year, fish aged 11 to 15 were within two years and fish aged 16 and over were within three years, the age determined by the primary reader was assigned. All other disagreements on the age were determined by a second independent reading. If there was still disagreement after two paired readings, a third reading was used to get a consensus age between both readers.

Lengths at age of capture were used to develop von Bertalanffy growth curves for each species. Total length was used for all species except shovelnose sturgeon where fork length was used. The von Bertalanffy growth equations were expressed as $L = L_{\infty} \times (1\text{-}e^{-kt})$ for length (mm), where L is the length of the fish (mm) at age t, L_{∞} is the theoretical size limit and k is the curvature parameter. Because of a shortage of small, likely young fish, the initial condition parameter was set at zero and a two-parameter model was fit. Estimates for von Bertalanffy growth parameters were calculated in SAS (SAS Institute Inc., Cary, NC).

Statistical Analysis

Some data were missing from the overall dataset. Data imputations were performed for habitat variables of temperature (6.57% missing), turbidity (8.02% missing) and depth (19.71% missing). Temperature was imputed using a parametric bootstrapping algorithm in the MICE package (van Buuren and Groothuis-Oudshoorn 2011) of R statistical programming language (R Core Team 2016). Depth and turbidity were imputed using a random forest algorithm (Doove et al. 2014) and all imputed data was checked manually for congruence to the underlying dataset.

Variables flow and turbidity were log10 transformed to meet assumptions of normality. Differences in species richness between sampling location and sampling gear were compared using a Kruskal-Wallis Rank Sum Test (Higgins 2004; Smith et al. 2015) with a Holm correction used to account for multiple comparisons of location and gears. Location averaged habitat variables (depth, turbidity, etc.) were also compared using the same method to analyze habitat characteristics among sampling locations.

Fish assemblage relationships were investigated for total catch using non-metric multidimensional scaling (NMDS). NMDS is a robust ordination technique that has been used to assess species assemblage relationships (Smith et al. 2015; Watkins et al. 2015). Ordination fit was evaluated by stress values with stress of less than 20.0 indicating good fit (McCune and Grace 2002). Fish assemblage was investigated using pooled total catch data from each location. Differences in assemblage structure were investigated with permutational multivariate analysis of variance (PERMANOVA) and significant vectors were fit to the NMDS with rotational vector fitting for total catch data.

Species-specific Models

In addition to investigations of species richness, habitat associations and fish assemblage structure, species-specific relationships with abiotic factors were investigated for presence/absence and total catch data with multiple regression models. Generalized linear models were used to identify abiotic factors most associated with occurrence and total catch of selected fish species. Sampling was conducted between 20 May and 11 August for both years and interactions between environmental conditions and time were investigated in candidate models. Sampling from 20 May to 30 June (Month 1) and 1 July to 11 August (Month 2), in addition to Year 1 and Year 2, were used in interactions with abiotic predictor variables to account for any temporal variability.

A binomial error distribution and logit link function were used for presence/absence models. An over-dispersion (variance > mean) parameter ($\hat{c}$) was calculated for global models for all species and used as an indication of data structure. Models with $\hat{c}$ over 1 were considered over-dispersed and Schwarz's Bayesian Information Criterion (Schwarz 1978; BIC) was used for model selection. The distribution for total catch models was selected by creating global models (models with the most parameters) for each species using Poisson and negative binomial error distributions and zero-inflated versions of both and BIC was used to rank the models with different distributional assumptions. The negative binomial distribution had the lowest BIC value for all species and was used for subsequent modeling of total catch data. Model fit was evaluated by using Spearman's rank correlations (ρ) between actual and predicted values of the response variable for each model considered plausible (Holbrook et al. 2016).

Prior to model fit, habitat characteristics were investigated for multicollinearity using Spearman's correlation coefficients to identify correlations between all pairs of habitat variables. *A priori* correlation of $|\rho| \geq 0.70$ would be considered highly correlated and variables would not be used together in candidate models. No highly correlated variable pairs were found.

The candidate occurrence and total catch models consisted of 7-13 *a priori*

models for each species. An information-theoretic approach was used to select the most parsimonious model among the candidate model set for each species (Burnham and Anderson 2002). Candidate models were ranked using BIC values and models with ΔBIC values of ≤ 2 were considered equally parsimonious and retained for interpretation. Results were not considered for species caught only in seines and for rare species because models did not seem meaningful and often did not converge. Models explaining use by environmental conditions and temporal interactions were developed for bigmouth buffalo, blue sucker, common carp (*Cyprinus carpio*), channel catfish, goldeye, river carpsucker, sauger, shorthead redhorse, shovelnose sturgeon, smallmouth buffalo and walleye.

Results

In all, 8,910 fish, representing 29 species, were captured; 4,953 (56%) in Year 1 (2002) and 3,957 (44%) in Year 2 (2003). For trammel nets, hoop nets and bag seines the percentage of fish caught was higher in Year 1 than in Year 2 and for stationary gill nets the percentage of fish caught was lower in Year 1 than Year 2. The ten most abundant species overall were native to the Milk and Missouri rivers (Table 1). Three of the native species, blue sucker, sauger and paddlefish are Montana species of special concern. Another native species, burbot (*Lota lota*), is a watch list species for Montana Natural Heritage Program, as are two members of the genus *Hybognathus*, the plains minnow (*Hybognathus placitus*) and brassy minnow (*Hybognathus hankinsoni*). There were also many non-native fishes caught (8 species), but generally as small percentages of fishes in a particular location or with a particular gear (Table 1).

Catches by species differed by year. Most of the blue suckers (88%) and shovelnose sturgeon (84%) were sampled in Year 1. In contrast, most walleye (88%), shorthead redhorse (76%) and sauger (61%) were sampled in Year 2. Most other species were sampled in similar proportions between years. Gravid fish of 11 different species, indicating reproductive readiness, were sampled in nearly equal proportion between hoop and gill nets, mainly during May and June. Gravid fish were generally caught at locations farther upstream, with location 5 having the highest number of gravid fish sampled (mainly shovelnose sturgeon).

Location 2 (Fig. 1) had the highest number of fish sampled and location 1 on the Missouri River, downstream of the confluence of the Milk and Missouri River and location 6 above Vandalia Dam, had the lowest number of fish sampled. Habitat characteristics were not significantly different between locations ($\chi^2 = 23$; 23 df; $P = 0.46$) suggesting fairly homogenous conditions in the lower Milk River. Species richness was significantly different between locations ($\chi^2 = 15.2081$; 5 df; $P = 0.01$) with significant pairwise differences between location 6 and locations 2 *(*$P = 0.03$) and 3 ($P = 0.01$).

Species richness was significantly different among gears ($\chi^2 = 28.507$; 4 df; $P < 0.01$) with significant pairwise differences between floating gill nets and hoop nets, siene and sinking gill nets ($P < 0.01$). Some species, in particular small minnows (*Cyprinidae*), were only caught with the small-meshed seine. These catches included fathead minnow ($n = 736$), longnose dace ($n = 65$), emerald shiner ($n = 1523$) and spottail shiner ($n = 16$). Overall, seine catches were greater later in the year (July and August). Four other species sampled by only one gear were caught in very low numbers ($n < 7$; Table 1).

The timing and duration of the spring seasonal discharge patterns over the period May to mid-August differed between Years 1 and 2. In Year 1, increased spring discharge lasted for 41 days, peaking at 62 m^3/s on 15 June and at 78 m^3/s on 28 June before dropping to < 10 m^3/s on 18 July. In Year 2, increased spring discharge lasted for only 17 days and occurred much earlier, peaking at 70 m^3/s on 12 May and before dropping to < 10 m^3/s on 28 May. The later peak in spring discharge in Year 1 was associated with higher rainfall in late spring,

Table 1. Percentage catch for each location or gear type. N = native fish, S = species of special concern and I = non-native species (Holton and Johnson 2003). DTN = drifting trammel net, FGN = floating gill net, SGN = sinking gill net. Species are abbreviated as follows black bullhead (BKBH), bigmouth buffalo (BMBF), burbot (BRBT), blue sucker (BUSK), common carp (CARP), channel catfish (CNCF), white crappie (CRPE), emerald shiner (ERSN), flathead chub (FHCB), fathead minnow (FHMW), freshwater drum (FWDM), goldeye (GDEY), *Hybognathus* (HBNS), longnose dace (LNDC), longnose sucker (LNSK), northern pike (NTPK), paddlefish (PDFH), rainbow trout (RBTT), river carpsucker (RVCS), sauger (SGER), shorthead redhorse (SHRH), smallmouth buffalo (SMBF), smallmouth bass (SMBS), shovelnose sturgeon (SNSG), stonecat (STCT), spottail shiner (STSN), walleye (WLYE), white sucker (WTSK) and yellow perch (YWPH).

		Location						Gear				
Species	**Status**	**1**	**2**	**3**	**4**	**5**	**6**	**DTN**	**FGN**	**HOOP**	**SEINE**	**SGN**
BKBH	I	0.00	0.00	0.05	0.12	0.00	0.00	0.00	0.00	0.08	0.00	0.04
BMBF	N	0.31	0.13	0.16	0.48	0.16	0.00	0.84	0.00	0.17	0.11	0.07
BRBT	S	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00
BUSK	S	4.66	7.18	1.15	0.00	0.00	0.00	3.77	59.46	10.44	0.02	3.00
CARP	I	0.93	2.53	3.24	3.26	0.81	4.36	11.11	0.00	0.76	2.18	1.68
CNCF	N	5.59	14.46	20.24	28.38	26.09	12.59	14.88	0.00	45.03	2.50	22.23
CRPE	I	0.00	0.03	0.00	0.48	0.00	1.21	0.00	0.00	0.08	0.11	0.14
ERSN	N	30.43	6.41	15.74	7.61	9.98	0.00	0.00	0.00	0.00	34.27	0.00
FHCB	S	6.21	11.13	10.75	0.48	1.45	0.00	0.21	0.00	0.25	18.74	0.36
FHMW	N	1.24	3.41	5.98	14.49	5.48	0.00	0.00	0.00	0.00	16.56	0.00
FWDM	N	0.00	0.10	0.22	0.60	0.00	1.69	0.00	0.00	0.08	0.14	0.43
GDEY	N	8.39	10.99	11.41	9.66	18.36	29.54	19.92	8.11	3.11	0.79	25.08
HBNS	S	6.21	4.59	2.08	3.86	0.48	0.00	0.00	0.00	0.00	8.39	0.00
LNDC	N	0.62	1.15	1.04	0.12	0.81	0.00	0.00	0.00	0.00	1.46	0.00
LNSK	N	0.31	0.10	0.00	0.00	0.16	0.00	0.21	0.00	0.08	0.09	0.00
NTPK	I	0.00	0.40	0.38	1.21	1.45	2.66	0.00	0.00	0.25	0.00	1.64
PDFH	S	0.62	0.03	0.00	0.00	0.00	0.00	0.42	2.70	0.00	0.00	0.00
RBTT	I	1.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00

Table 1. continued next page

Table 1. continued

		Location						Gear				
Species	**Status**	**1**	**2**	**3**	**4**	**5**	**6**	**DTN**	**FGN**	**HOOP**	**SEINE**	**SGN**
RVCS	N	8.39	20.80	8.78	10.27	5.15	17.68	22.22	24.32	22.39	5.47	19.55
SGER	N	3.42	3.24	2.74	1.45	0.97	0.00	3.98	0.00	1.85	0.41	4.14
SHRH	N	12.42	5.87	8.72	8.45	20.77	12.35	5.24	0.00	10.02	5.49	11.56
SMBF	N	0.31	4.11	3.62	7.25	4.83	5.57	5.45	0.00	4.63	1.19	4.78
SMBS	I	0.00	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.08	0.05	0.04
SNSG	N	4.66	1.58	2.80	0.00	0.00	0.00	10.48	5.41	0.08	0.00	2.21
STCT	N	0.00	0.07	0.22	0.36	0.00	0.00	0.00	0.00	0.08	0.09	0.14
STSN	I	0.31	0.24	0.16	0.24	0.48	0.00	0.00	0.00	0.00	0.36	0.00
WLYE	I	0.00	0.30	0.27	0.97	1.29	11.38	0.00	0.00	0.25	0.00	2.64
WTSK	N	3.42	1.11	0.11	0.24	0.48	0.00	1.26	0.00	0.17	1.44	0.04
YWPH	I	0.00	0.00	0.00	0.00	0.48	0.97	0.00	0.00	0.00	0.00	0.21

whereas the peak in Year 2 was associated with snowmelt runoff.

Blue sucker and shovelnose sturgeon catches also differed greatly between years. In Year 1, two hoop nets caught 124 blue suckers at location 2 on 10 June, before the first discharge peak. Fifty shovelnose sturgeon were caught in one stationary gill net at location 3 on 17 June, between the two discharge peaks. In the following year, in which peak flows occurred earlier and only one peak occurred, blue suckers and shovelnose sturgeon were not captured during the peak in discharge. Total catches for these two species were also lower than in the previous year.

The NDMS ordination characterized differences in fish assemblage structure by location. The NMDS for total catch data, which indicated species associations with location and habitat vectors, showed strong associations for catches with low totals and locations at the periphery of the study area. For instance, longnose sucker, rainbow trout, paddlefish and black bullheads were associated with location 1 below the confluence of the Milk River with the Missouri River and black crappie and yellow perch were associated with location 6, the only location above Vandalia Dam (Fig. 2). Species with higher catch numbers clustered around locations in the middle of the ordination plot and appeared to be associated with locations in the middle of our sampling area: location 2 (blue sucker, bigmouth buffalo, shovelnose sturgeon and white sucker), location 3 (emerald shiner, longnose dace) and location 4 (sauger, walleye, river carpsucker and smallmouth buffalo) (Fig. 2).

In models explaining environmental conditions and temporal interactions for individual species, results for occurrence (Table 2)

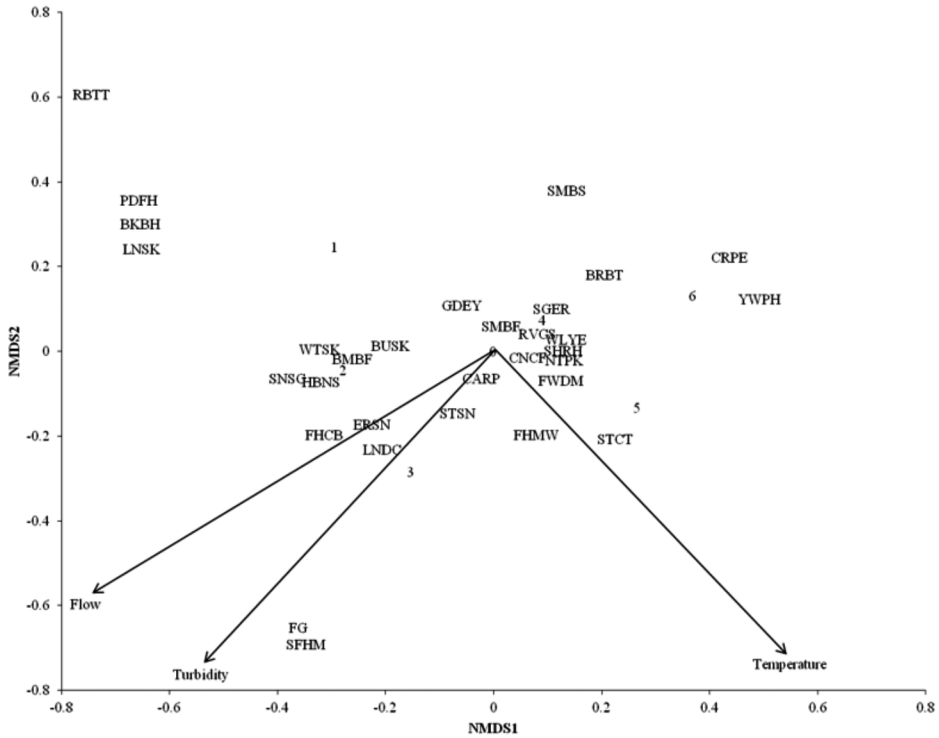

Figure 2. Nonmetric multidimensional scaling ordination (stress = 0.8) of the fish assemblage structure using total catch data from six sites in the Milk and Missouri Rivers. Significant ($P \leq 0.05$) habitat vectors are included and sites are delineated by number, but 0 delineates the origin, not a site. Reference Table 1 for species codes.

and total catch (Table 3) were very similar for most species. Blue sucker, common carp, channel catfish, goldeye, shorthead redhorse, shovelnose sturgeon, smallmouth buffalo and walleye all had models of almost equal parsimony for both occurrence and abundance with the same explanatory variables (Tables 2 and 3). River carpsucker and sauger were the only species to have no explanatory variables in common between parsimonious models for occurrence and abundance (Tables 2 and 3). Blue sucker, common carp and shorthead redhorse were all significantly positively associated with turbidity while walleye were significantly negatively associated with turbidity. Shorthead redhorse occurrence was also significantly positively associated with a turbidity and Year 2 interaction. Channel catfish and smallmouth buffalo were positively associated with temperature, as was the abundance of river carpsucker and sauger. Shovelnose sturgeon were positively associated with flow, while goldeye were significantly negatively associated with the flow by Month 2 (July/August) interaction.

Age and Growth

In all, 508 fish were aged in this study: 189 channel catfish, 28 northern pike, 146 sauger, 72 shovelnose sturgeon and 73 walleye (Table 4). Mean lengths at age were calculated for aged fish and varied from 330 mm at age 5 to 615 mm at age 21 for channel catfish, from 287 mm at age 2 to 542 mm at age 13 for sauger, from 271 mm at age 2 to 725 mm at age 16 for walleye, from 386 mm at age 2 to 810 mm at age 10 for northern pike and from 538 mm at age 8 to 637 mm at age 22 for shovelnose sturgeon. Length weight equations and von Bertalanffy growth models were developed

Table 2. Occurrence models using logistic regression for important native and recreational species of the lower Milk River. Model selection criteria and c-hat (**ĉ**) are reported. **ĉ** gives an idea of overdispersion in the underlying dataset with values ≤ 1 indicating no overdispersion.

Species	Model	BIC	ΔBIC	-Log(l)	ĉ	Weight
Blue Sucker	+LogTurb,-LogTurb:Month2	139.6	0.00	-62.41	0.97	0.48
	+Temp,-Temp:Month1	141.0	1.41	-63.12	0.97	0.24
Common Carp	+LogTurb	177.0	0.00	-83.57	1.21	0.78
Channel Catfish	+Temp	156.0	0.00	-73.06	1.06	0.77
Goldeye	+LogTurb	197.9	0.00	-94.04	1.40	0.23
	-LogFlow	198.0	0.10	-94.09	1.40	0.22
	+Depth	198.3	0.39	-94.23	1.40	0.19
	-Temp	198.4	0.52	-94.29	1.40	0.18
	-LogFlow,-LogFlow:Month2	199.3	1.42	-94.29	1.40	0.12
River Carpsucker	+LogTurb	190.9	0.00	-90.53	1.36	0.53
Sauger	+LogTurb	190.3	0.00	-90.23	1.34	0.66
Shorthead Redhorse	+LogTurb,+LogTurb:Year2	187.8	0.00	-86.50	1.40	0.91
Shovelnose Sturgeon	+LogFlow	90.5	0.00	-40.31	0.52	0.84
Smallmouth Buffalo	+Temp	190.8	0.00	-90.46	1.33	0.81
Walleye	+Temp,+Temp:Year2	133.5	0.00	-59.38	0.88	0.40
	-LogTurb	134.9	1.35	-62.52	0.88	0.20

for all species used in age and growth analyses and are summarized in Table 4.

The overall pattern of *Wr* shows Milk River fishes had low condition on average, with the possible exception of northern pike and river carpsucker (Table 5). The average *Wr* of smallmouth buffalo (74) was the lowest of all species analyzed. The *K* values were variable due to the differences in body type of species sampled. The two species without *Wr* equations, blue sucker and goldeye, had condition factors less than 1 (Table 5).

Discussion

The ten most abundant species caught in our sampling were all native to the Milk and Missouri rivers, which indicates the Milk River provides important habitat for a variety of native species. One of the ten species, the blue sucker, is a Montana species of special concern; another species, the flathead chub, is much reduced throughout its range (Rahel and Thel 2004). As the largest tributary to the Missouri River between Fort Peck Dam and the confluence of the Yellowstone River (375 rkm), the high incidence of native fish fauna in the Milk River has important conservation implications. The Missouri River fauna below mainstem dams, including Fort Peck, has changed from species uniquely adapted for life in turbid waters with fluctuating flows and temperatures such as flathead chub and blue

Table 3. Total catch models using negative binomial regression for important native and recreational fish of the lower Milk River. Model selection criteria are reported as a way to assess model fit and support relative to other candidate models.

Species	Model	BIC	ΔBIC	-Log(*l*)	ρ	Weight
Blue Sucker	+LogTurb,-LogTurb:Month2	269.9	0.00	-138.61	0.32	0.65
Common Carp	+LogTurb	380.7	0.00	-182.97	0.25	0.89
Channel Catfish	+Temp	884.6	0.00	-434.94	0.30	0.61
	+Temp,+LogTurb,+Depth,-LogFlow	885.7	1.04	-428.08	0.37	0.36
Goldeye	-LogFlow,-LogFlow:Month1	649.4	0.00	-314.87	0.19	0.59
River Carpsucker	+Temp,-Temp:Month2	773.0	0.00	-376.64	0.31	0.93
Sauger	+Temp,-Temp:Month2	428.2	0.00	-204.27	0.28	0.93
Shorthead Redhorse	+LogTurb,+LogTurb:Year2	652.2	0.00	-316.24	0.36	0.62
	-Temp,+Temp:Year2	653.4	1.27	-316.87	0.35	0.33
Shovelnose Sturgeon	+LogFlow	175.8	0.00	-80.53	0.33	0.92
Smallmouth Buffalo	+Depth	529.4	0.00	-257.30	0.13	0.27
	+Temp,-Temp:Month2	529.6	0.22	-254.95	0.23	0.24
	+Temp	529.9	0.55	-257.58	0.21	0.21
	-LogFlow	531.2	1.80	-258.21	-0.01	0.11
	-LogTurb	531.3	1.92	-258.26	-0.14	0.10
Walleye	-LogTurb	206.3	0.00	-95.75	0.21	0.90

sucker to pelagic planktivores and sight-feeding predators such as emerald shiners and walleye (Pflieger and Grace 1987; Rabeni 1996; Everett et al. 2004). Milk River habitat for native species has thus assumed greater importance than before Missouri River main channel alterations.

The significantly lower species richness in location 6, above Vandalia Dam, than locations 2 and 3, is consistent with results of Stash et al. (2001). Species richness was greater further downstream in the Milk River and there were differences above and below Vandalia Dam (Stash et al. 2001). The main factor associated with this difference in our study and that of Stash et al. (2001) is the diversion dam, which acts as a barrier to fish movement in all flows (Stash et al. 2001). Barriers impeding dispersal have been shown to be detrimental to other Great Plains systems and fishes (Cross et al. 1985; Bestgen and Platania 1990, 1991; Winston et al. 1991; Fausch and Bestgen 1997; Luttrell et al. 1999; Matthews and Marsh-Matthews 2007). There can be successful re-colonization of habitat by native fishes if fish passage is provided (McKoy 2013) but special considerations must be made for certain species that resist passage (e.g., shovelnose sturgeon; White and Mefford 2002). Our results emphasize the need to provide fish passage at such dams whenever possible to assist spawning success of native species.

Table 4. Age and growth results showing the species aged (reference Table 1 for species codes) and total numbers used in age and growth analysis. Fish sizes, ages and both length weight equations and von Bertalanffy growth equations were calculated for age and growth analysis.

Species	*n* (aged)	Age		Length (mm)			Weight (g)			Length Weight Equation	von Bertalanffy Growth Equation
		Min	Max	Mean (SE)	Min	Max	Mean (SE)	Min	Max		
CNCF	739(189)	5	21	397(101)	20	740	608(543)	0.1	4200	$\log_{10}W=2.9966\log_{10}L-5.1065$ ($r^2=0.97$)	$L=631.5(1-e^{(-0.1249t)})$
SGER	157(146)	2	13	326(63)	220	543	294(207)	50	1330	$\log_{10}W=2.86\log_{10}L-4.79$ ($r^2=0.81$)	$L= 427(1-e^{(-0.335t)})$
WLYE	82(73)	2	16	418(139	196	867	820(945)	50	4400	$\log_{10}W=2.761\log_{10}L-4.47$ ($r^2=0.87$)	$L=649.7(1-e^{(-0.196t)})$
NTPK	59(28)	2	10	634(158)	326	926	1832(1135)	250	4300	$\log_{10}W=2.70\log_{10}L-4.38$ ($r^2=0.87$)	$L=864(1-e^{(-0..2717t)})$
SNSG	114(72)	8	22	620(65)	465	805	997(391)	300	2650	$\log_{10}W=3.38\log_{10}L-6.47$ ($r^2=0.89$)	$L=733.7(1-e^{(-0.1341t)})$

The presence of many gravid fish during spring flows is consistent with other studies (Geen et al. 1965; Cross 1967; Curry and Spacie 1984; Walters et al. 2014). Those authors have concluded that the fish may be keying in on elements of the hydrograph for preferable environmental conditions for spawning, as would be expected for Great Plains fishes (Fausch and Bestgen 1997). Our study supports this conclusion. In the lower Milk River study area, the month of June has the highest seasonal rainfall with 21.5 percent of the yearly total precipitation (Western Regional Climate Center 2001). The typical Milk River spring hydrograph most likely had two distinct peaks, the first from mountain and highland snow melt and the second from spring rainfall or late season snow, which would correspond to the natural pattern in the hydrograph for Great Plains rivers. Eggs are deposited in the water column upstream during high flows to protect them from abrasion with the fine, silty substrates (Fausch and Bestgen 1997). After the larvae hatch they can drift with the current towards suitable rearing habitat. In Wyoming, for example, goldeye moved upstream into Crazy Women Creek and deposited eggs; the eggs then drifted and hatched downstream in the Powder River (Smith and Hubert 1989). In the current study, many of the Missouri River migratory fish were captured in the Milk River during the period of high discharge in June. In the late spring and early summer of Year 1, there were two peaks in discharge (14 June and 28 June). For example, during the period of high discharge from 10 June to 13 July, 222 blue suckers (63%), 9 paddlefish (100%) and 108 shovelnose sturgeon (62%) were caught. The higher catches during this period is indicative of increased use and movement during high flows as fish migrate upriver in preparation for spawning. In addition, a higher percentage of juvenile fish were sampled at downstream locations, in contrast

Table 5. Fish condition metrics for species with standard weight equations or important native species with large total catch.

Species (n)	W_r Citation	Mean Wr (SE)	Mean K (SE)	Length (mm)		
				Mean	Min	Max
Bigmouth Buffalo (8)	Bister et al. 2000	85 (4)	1.55 (0.08)	641.9	492	784
Blue Sucker (241)	--	--	0.82 (0.01)	692	531	806
Common Carp (86)	Bister et al. 2000	87 (1.4)	1.23 (0.02)	494.8	250	730
Channel Catfish (828)	Brown et al. 1995	86 (1)	0.79 (0.01)	398.4	78	740
Freshwater Drum (12)	Blackwell et al. 1995	99 (6)	1.28 (0.08)	404.4	332	460
Goldeye (398)	--	--	0.92 (0.03)	295.2	145	438
Northern Pike (40)	Anderson and Neumann 1996	101 (14)	0.68 (0.09)	677.6	326	906
River Carpsucker (577)	Bister et al. 2000	101 (1)	1.4 (0.01)	470.5	195	690
Sauger (152)	Anderson and Neumann 1996	79 (2)	0.75 (0.02)	326.6	220	543
Shorthead Redhorse (297)	Bister et al. 2000	99 (4)	1.14 (0.05)	366.8	120	565
Smallmouth Buffalo (195)	Bister et al. 2000	74 (1)	1.39 (0.01)	548.1	354	710
Shovelnose Sturgeon (112)	Quist et al. 1998	91 (1)	0.39 (0.01)	619.2	465	805
Walleye (68)	Murphy et al. 1990	84 (4)	0.87 (0.04)	435.6	210	867
White Sucker (9)	Bister et al. 2000	88 (6)	1.08 (0.08)	398	152	527

to many gravid adult fish sampled at location 5. Gravid fish at upstream locations indicates use of the Milk River for spawning, similar to other studies (Peterson and VanderKooy 1995; Walters et al. 2014) that found adults using upstream riffle habitat to spawn, enabling larval fish to drift downstream into suitable rearing habitats.

The modeling of occurrence and abundance provided insights on what environmental conditions influence use of the Milk River by many native and nonnative species. Temperature and turbidity were identified as the most important variables for predicting occurrence and relative abundance of most species. The environmental conditions explained the occurrence and relative abundance of many fishes, similar to results in other locations (Geen et al. 1965; Cross 1967; Curry and Spacie 1984; Walters et al. 2014). The modeling data suggest native species key on aspects of the natural hydrograph to complete portions of their life history. Care must be taken to ensure that additional habitat is not lost due to anthropogenic disturbances of the Milk River.

Age and growth analysis on several fish species, including channel catfish, sauger, walleye, northern pike and shovelnose sturgeon indicates that many of the fish are slower growing and longer lived than commonly found elsewhere. The maximum age estimated for channel catfish in our study was 21y, compared to the maximum age from the

Missouri River, Montana of 18y (Berg 1981) and 24y in the Red River, North Dakota (Hegrenes 1992). Channel catfish ages in southern latitudes have rarely been reported to exceed 10y (Carlander 1969). The size of channel catfish was also similar to those reported for other populations across their distribution in the United States (Carlander 1969). In an assessment of 102 channel catfish age and growth studies, Hubert (1999) found no differences in regional size patterns. In the Red River, North Dakota, Hegrenes (1992) found size and not age to be important in determining maturation. The age of maturity reported by Hubert (1999), in contrast, was strongly related to the latitude; fish in southern latitudes matured earlier than fish in northern latitudes.

The age distribution of the sauger (Braaten and Guy 2002) and northern pike (Wolfert and Miller 1978) in the Milk River was consistent with other populations at similar latitudes. The maximum age of walleye in the Milk River (16 y) is greater than reported for other populations in northern latitudes. The maximum age was 10 y in the Missouri River, Montana (Berg 1981) and 12 y in the Mississippi River, Wisconsin (Becker 1983). The average life expectancy is typically 5–7 y in southern latitudes and 12–15 y in northern latitudes (Colby and Nepszy 1981).

The mean length-at-age for shovelnose sturgeon in the Milk River (465–805 mm) was similar to results reported in the Missouri River, downstream of Ft. Peck dam to the confluence of the Yellowstone River (472–732 mm; Gardner and Stewart 1987), but lower than the populations in the Yellowstone River, Montana (202–996 mm; Everett et al. 2003) and the Missouri River, Montana (566–914 mm; Berg 1981) upstream of Fort Peck Dam. The sturgeon in the Milk River grew significantly slower than fish in the Yellowstone River; the curvature parameter, k, was significantly lower for the Milk River ($\chi^2 = 35.65$; 2 df; $P < 0.001$) as was the asymptotic length, $L\infty$ ($\chi^2 = 357.51$; 2 df; $P < 0.001$) compared to the Yellowstone River. One sampled fish was a male that was not yet reproductively ready and was estimated to be age 8. Shovelnose sturgeon typically reach sexual maturity about age 5 for males and age 7 for females (Hurley and Nickun 1984). Gardner and Stewart (1987) and Quist et al. (2002) reported the fish inhabiting the lower Missouri River below Ft. Peck Dam to be slower growing than fish from the Missouri River above Fort Peck reservoir. The mean differences in length-at-age among river segments may be related to the cold-water releases at Fort Peck Dam. Everett et al. (2003) found that shovelnose sturgeon in the Yellowstone River, with mean monthly water temperature 7°C warmer during summer, grew faster than shovelnose sturgeon in the Missouri River below Garrison Dam. The Yellowstone River is less extensively altered than most other large rivers, with only six low head diversion dams (Helfrich et al. 1999). Fish captured in the Milk River have also been captured in the Yellowstone River (D. Fuller, Montana Department of Fish, Wildlife and Parks, personal communication). A study on the movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri River (Bramblett and White 2001) found that shovelnose sturgeon mostly occupy the Yellowstone River, avoiding impounded areas, whereas pallid sturgeon made seasonal migrations into the Missouri River. We expect shovelnose sturgeon found in the Milk River spend much of their time in the main channel of the Missouri River and less time in the Yellowstone River. Observed differences in shovelnose sturgeon age and growth between rivers thus may have more ecological significance than if the fish moved widely between rivers.

Overall, the length-at-age and maximum age of most species in this study was consistent with other populations in northern latitudes and fish generally grew slower and lived longer than populations farther south, similar to the results of Bratten and Guy (2002). It is also consistent with the higher metabolic and more rapid movement through life stages commonly associated with various fish species with warmer waters (Scarnecchia et al. 2011).

The later maturation and longer lifespan of native species in the Milk River may also make them more vulnerable to short term environmental stochasticity. Population depletions could take longer to recover in the Milk River than in populations with faster growth and earlier maturity.

Results of this study indicate that the Milk River probably provides important spawning habitat for shovelnose sturgeon, blue suckers and other species. The sturgeon, which typically occupies large turbid rivers with high current velocities (Carlson et al. 1985), is only sampled in the Milk River during high spring flows (Fuller 2000 and 2002). No shovelnose sturgeon have been sampled in in the Milk River during fall sampling (Fuller 2000 and 2002; Stash 2001). In spring, however, many gravid males (running milt; 31) and a single gravid female (ovulated eggs) were captured during our sampling. Other females, however, may have had mature eggs that were not yet ovulated and thus not expelled upon handling.

Similarly, the large number of blue suckers in spring provides strong evidence of the importance of the Milk River as spawning habitat. Although they are generally known as an inhabitant of the Mississippi and Missouri rivers (e.g., Rupprecht and Jahn 1980), blue suckers are well-known to be highly migratory (Neely et al. 2009) and are also known to spawn in mid-sized, turbid tributaries, such as the Neosho River, a tributary of the Arkansas River (Moss et al. 1983) the Grand River in North-central Missouri (Vokoun et al. 2003) and the James and Big Sioux rivers in South Dakota (Morey and Berry (2003). In some cases, they are known in rivers only from spawning specimens (e.g., Vokoun et al. 2003). Several pieces of evidence support the idea that blue suckers sampled in this study were on a spawning migration, including the most effective sampling on the increasing hydrograph, the aggregated nature of the fish and catches and the presence of running milt and developed roe (Bednarski 2004; Bednarski and Scarnecchia 2006).

The occurrence and abundance of native fish in the Milk River, in contrast to the altered fish fauna in the Missouri River, is likely a result of the Milk River retaining more attributes of a natural Great Plains river. The Milk River retains many natural characteristics for 188 rkm below Vandalia Dam, compared to the clear, cold, highly regulated, channelized Missouri River into which it flows. The mouth of the Milk River is 200 rkm upstream of the confluence of the Missouri and Yellowstone Rivers where there are more natural floodplains and backwater habitats (Shields et al. 2000), which are critical habitat for spawning and rearing of native fish. The Milk River has remained turbid and warm with irregular flows and acts as a refuge for native fish in this section of the Missouri River system (Everett et al. 2004). Efforts are needed to ensure that habitat is not further degraded by additional modifications or irrigation withdrawals. Additionally, large reaches of riverine habitat need to be preserved to improve current conditions and allow for the environmental conditions needed by riverine species to carry out their life histories.

Acknowledgements

B. Dennis, J. Braatne, J. Firehammer and R. Long provided technical and statistical assistance. We also thank B. Parker, D. Henry and K. Hell for field and laboratory assistance. Additional technical assistance was kindly provided by P. Braaten, D. Fuller, M. Ruggles, F. McDonald, M. Baxter, J. Remis, B. J. Erickson. An earlier version of this manuscript was improved by the comments of two anonymous reviewers. Funding was provided by Montana Fish, Wildlife and Parks and the U.S. Bureau of Reclamation.

Literature Cited

Alden, W.C., 1932. Physiography and glacial geology of eastern Montana and adjacent areas (No. 174). U. S. Government Printing Office, Washington DC.

Anderson, R. O. and R. M. Neumann. 1996. Length, weight and associated structural indices. Pages 447–482 in B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press. Madison. 1052 pp.

Bednarski, J. 2004. Ecology of fishes in the lower Milk River, Montana in relation to spring discharge. Master of Science Thesis, University of Idaho, Moscow.

Bednarski, J. and D.L. Scarnecchia. 2006. Age structure and reproductive activity of the blue sucker in the Milk River, Missouri River Drainage, Montana. Prairie Naturalist 38:167–182.

Benda, L., K. Andras, D. Miller and P. Bigelow. 2004. Confluence effects in rivers: interactions of basin scale, network geometry and disturbance regimes. Water Resources Research, 40.

Berg, R. K. 1981. Fish populations of the wild and scenic Missouri River. Montana Department of Fish, Wildlife and Parks. Federal Aid to Fish and Wildlife Restoration, Project FW-3-R, Job I-A, Montana. Helena.

Bestgen, K. R. and S. P. Platania. 1990. Extirpation of Notropis simus simus (Cope) and Notropis orca Woolman (Pisces: Cyprinidae) from the Rio Grande in New Mexico, with notes on their life history. Occasional Papers the Museum of Southwestern Biology 6:1–8.

Bestgen, K. R. and S. P. Platania. 1991. Status and conservation of the Rio Grande Silvery Minnow, *Hybognathus amarus*. Southwestern Naturalist 36:225–232.

Bister, T. J., D. W. Willis, M. L. Brown, S. M. Jordan, R. M. Neumann, M. C. Quist and C. S. Guy. 2000. Proposed standard weight (W_s) equations and standard length categories for 18 warmwater nongame and riverine fish species. North American Journal of Fisheries Management 20:570–574.

Blackwell, B. G., M. L. Brown and B. R. Murphy. 1995. Development and evaluation of a standard weight (W_s) equation for freshwater drum. Prairie Naturalist 27:51–61.

Borkholder, B. D. and A. J. Edwards. 2001. Comparing the use of dorsal fin spines with scales to back-calculate length-at-age estimates of walleyes. North American Journal of Fisheries Management 21:935–942.

Braaten, P. J. and C. S. Guy. 2002. Life history attributes of fishes along the latitudinal gradient of the Missouri River. Transactions of the American Fisheries Society 131:931–945.

Bramblett, R. G. and R. G. White. 2001. Habitat use and movements of pallid and shovelnose sturgeon in the Yellowstone and Missouri Rivers in Montana and North Dakota. Transactions of the American Fisheries Society 130:1006–1025.

Brown, M. L., F. Jaramillo, Jr., D. M. Gatlin, III and B. R. Murphy. 1995. A revised standard weight (W_s) equation for channel catfish. Journal of Freshwater Ecology 10:295–302.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multi-model inference: a practical information theoretic approach, 2nd edition. Springer-Verlag: New York.

Carlander, K. D. 1969. Handbook of freshwater fishery biology, Volume 1. Iowa State University Press, Ames.

Carlson, D. M. and W. L. Pflieger, L. Trial and P. S. Haverland. 1985. Distribution, biology and hybridization of *Scaphirhynchus albus* and *S. platorynchus* in the Missouri and Mississippi Rivers. Environmental Biology of Fishes 14:51–59.

Casselman, J. 1974. Analysis of hard tissue of pike *Esox lucius* L. with special reference to age and growth. Pp. 13–27 *in* T. B. Bagenal, editor, The aging of fish. Unwin Brothers, Limited. Surrey, England.

Colby, P. J. and S. J. Nepszy. 1980. Variation among stocks of walleye (*Stizostedion vitreum*) management implications. Canadian Journal of Fisheries and Aquatic Sciences 38:1814–1831.

Cross, F. B. 1967. Handbook of fishes of Kansas. Museum of Natural History, University of Kansas. Miscellaneous Publication 45: 1–357.

Cross, F. B., R. E. Moss and J. T. Collins. 1985. Assessment of dewatering impacts on stream fisheries in the Arkansas and Cimarron rivers. Museum of Natural History, University of Kansas, Lawrence.

Curry, K. D. and A. Spacie. 1984. Differential use of stream habitat by spawning catostomids. American Midland Naturalist 111:267–279.

DeVries, D. R. and R. V. Frie. 1996. Determination of age and growth. Pp. 483–508 *in* B. R. Murphy and D. W. Willis, editors, Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Dingman, K. 2001. Sectioning and aging manual for white sturgeon (*Acipenser transmontanus*), pallid sturgeon (*Scaphirynchus albus*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), walleye (*Stizostedion vitreum*), blue sucker (*Cycleptus elongatus*) and Flannelmouth sucker (*Catostomus latipinnis*), Unpublished. University of Idaho, Moscow.

Doove, L. L., S. van Buuren and E. Dusseldorp. 2014. Recursive partitioning for missing data imputation in the presence of interaction Effects. Computational Statistics & Data Analysis 72:92–104.

Everett, S. R., D. L. Scarnecchia, G. J. Power and C. J. Williams. 2003. Comparison of age and growth of shovelnose sturgeon in the Missouri and Yellowstone Rivers. North American Journal of Fisheries Management 23:230–240.

Everett, S., D. L. Scarnecchia and F. Ryckman. 2004. Distribution and habitat use of sturgeon chubs (*Macrhybopsis gelida*) and sicklefin chubs (*M. meeki*) in the Missouri and Yellowstone Rivers, North Dakota. Hydrobiologia 527:183–193.

Fausch, K. D. and K. R. Bestgen. 1997. Ecology of fishes indigenous to the central and southwestern Great Plains. Pp. 131–166 *in* F. L. Knopf and F. B. Samson, editors. Ecology and Conservation of Great Plains Vertebrates. Springer-Verlag, New York.

Fuller, D. B. 2000. Community structure, habitat use and distribution of Milk River fishes, 1999 annual progress report. Montana Department of Fish, Wildlife and Parks, Fort Peck.

Fuller, D. B. 2002. Lower Milk River fishery study 2001 report. Fort Peck, Montana, Montana Department Fish Wildlife and Parks, Fort Peck.

Gardner, W. M. and P. A. Stewart. 1987. Lower Missouri River basin investigations, planning inventory, fisheries. Montana Department Fish Wildlife and Parks. Federal Aid to Fish and Wildlife Restoration project FW-2-R Job I-b. Helena.

Geen, G. H., T. G. Northcote, G. F. Hartman and C. C. Lindsey. 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet stream spawning. Journal of the Fisheries Board of Canada 23:1761–1788.

Hegrenes, S. G. 1992. Age, growth and reproduction of channel catfish in the Red River of the North. Master's thesis. University of North Dakota, Grand Forks.

Helfrich, L. A., C. Liston, S. Hiebert, M. Albers and K. Frazer. 1999. Influence of low-head diversion dams on fish passage, community composition and abundance in the Yellowstone River, Montana. Rivers 7:21–32.

Higgins, J. J. 2004. An introduction to modern nonparametric statistics. Brooks/ Cole Cengage Learning: Belmont, California.

Holbrook, J. D., R. S. Arkle, J. L. Rachlow, K. T. Vierling, D. S. Pilliod and M. M. Wiest. 2016. Occupancy and abundance of predator and prey: implications of the fire-cheatgrass cycle in sagebrush ecosystems. Ecosphere 7:e01307.

Hubert, W. A. 1999. Biology of channel catfish. Pp. 3–22 *in* E. R. Irwin, W. A. Hubert, C. F. Rabeni, H. L. Schramm, Jr. and T. G. Coon, editors, Catfish 2000: Proceedings of the International Ictalurid Symposium. American Fisheries Society, Symposium 24, Bethesda, Maryland.

Hurley, S. T. and J. G. Nickum. 1984. Spawning and early life history of shovelnose sturgeon. Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, Project Segment 2-399-R-1, Completion Report. Ames.

Hynes, H. B. N. 1989. Keynote Address. Pp. 5–10 in D. P. Dodge, editor. International Large River Symposium (LARS). Canadian Special Publication Fisheries and Aquatic Sciences 106. Ottawa, Ontario, Canada.

Koch, J. D., W. S. Schreck and M. C. Quist. 2008. Standardized removal and sectioning locations for shovelnose sturgeon fin rays. Fisheries Management and Ecology 15:139–145.

Luttrell, G. R., A. A. Echelle, W. L. Fisher and D. J. Eisenhour. 1999. Declining status of two species of the *Macrhybopsis aestivalis* complex (Teleostei: Cyprinidae) in the Arkansas River basin and related effects of reservoirs as barriers to dispersal. Copeia 1999:981–989.

Matthews, W. J. and E. Marsh-Matthews. 2007. Extirpation of Red Shiner in direct tributaries of Lake Texoma (Oklahoma–Texas): a cautionary case history from a fragmented river–reservoir system. Transactions of the American Fisheries Society 136:1041–1062.

McCune, B. and J. B. Grace. 2002. Analysis of ecological communities. MJM Softwear Design, Gleneden Beach, Oregon.

McKoy, K. P. 2013. Southeastern Montana warmwater investigation. Montana Department of Fish, Wildlife and Parks. Federal Aid Job Progress Report F-78-R3, Helena.

Milk River Watershed Council Canada. 2013. Milk River Transboundary State of the Watershed Report, 2nd Edition. Compiled by PalliserEnvironmental Services Ltd. and prepared for Milk River Watershed Council Canada (Alberta) in collaboration with the Milk River Watershed Alliance (Montana). Milk River, Alberta. 238 pp.

Montana Department of Health and Environmental Sciences. 1974. Water quality inventory and management plan, Milk River basin, Montana. Helena.

Montana Department of Natural Resources and Conservation. 1990. Special report summarizing the Milk River water supply. Helena.

Morey, N. M. and C. R. Berry, Jr. 2003. Biological characteristics of the blue sucker in the James River and the Big Sioux River, South Dakota. Freshwater Ecology 18:33–41.

Moss, R. E., J. W. Scanlan and C. S. Anderson. 1983. Observations on the natural history of the blue sucker (*Cycleptus elongatus LeSueur*) in the Neosho River. The American Midland Naturalist 109:15–22.

Moyle, P. B. and J. F. Mount. 2007. Homogenous rivers, homogenous faunas. Proceedings of the National Academy of Sciences 104:5711–5712.

Murphy, B. R., M. L. Brown and T. A. Springer. 1990. Evaluation of the relative weight (W_r) index, with new applications to walleye. North American Journal of Fisheries Management 10:85–97.

Neely, B. C., M. A. Pegg and G. E. Mestl. 2009. Seasonal use distributions and migrations of blue sucker in the middle Missouri River. Ecology of Freshwater Fish 18:437-444.

Peterson, M. S. and S. J. Vanderkooy. 1995. Phenology and spatial and temporal distribution of larval fishes in a partially channelized warmwater stream. Ecology of Freshwater Fish 4:93–105.

Pflieger, W. L. and T. B. Grace. 1987. Changes in the fish fauna of the lower Missouri River, 1940–1983. Pp. 166–192 *in* W. J. Matthews and D. C. Heins, editors, Community and evolutionary ecology of North America stream fishes. University of Oklahoma Press, Norman.

Quist, M. C., C. S. Guy and P. J. Braaten. 1998. Standard weight (W_s) equation and length categories for shovelnose sturgeon. North American Journal of Fisheries Management 18:992–997.

Quist, M. C., C. S. Guy, M. A. Pegg, P. J. Braaten, C. L. Pierce and V. H. Travnichek. 2002. Potential influence of harvest on shovelnose sturgeon populations in the Missouri River System. North American Journal of Fisheries Management 22:537–549.

R Core Team. 2016. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: http://www.R-project.org/.

Rabeni, C. F. 1996. Prairie legacies- fish and aquatic resources. Pp. 111–124 in F.B. Samson and F. L. Knopf, editors, Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington D. C.

Rahel, F. J. and L. A. Thel. 2004. Flathead Chub (*Platygobio gracilis*): a technical conservation assessment. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Species Conservation Project, Golden, Colorado. Available: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5182082.pdf. (April 2016).

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1–382.

Ruelle, R. and P. L. Hudson. 1977. Paddlefish (*Polyodon spathula*): growth and food of young of the year and a suggested technique for measuring length. Transactions of the American Fisheries Society 106:609–613.

Rupprecht, R. J. and L. A. Jahn. 1980. Biological notes on blue suckers in the Mississippi River. Transactions of the American Fisheries Society 109:323–326.

SAS Institute Inc. 1999. SAS/STAT User's guide, version 8. SAS Institute Inc. Cary, North Carolina.

Scarnecchia, D.L., B.D. Gordon, J.D. Schooley, L.F. Ryckman, B.J. Schmitz, S.E. Miller and Y. Lim. 2011. Southern and northern Great Plains (United States) paddlefish stocks within frameworks of Acipenseriform life history and the metabolic theory of ecology. Reviews in Fisheries Science 19:279–298.

Schwarz, G. 1978. Estimating the dimension of a model. The Annals of Statistics 6:461–464.

Shields, F. D., A. Simon and L. J. Steffen. 2000. Reservoir effects in downstream river channel migration. Environmental Conservation 27:54–66.

Simonds, M. J. 1998. The Milk River Project; 2nd draft. United States Bureau of Reclamation History Program. Denver, Colorado.

Smith, C. D., M. C. Quist and R. S. Hardy. 2015. Fish assemblage structure and habitat associations in a large western river system. River Research and Applications 32:622-638.

Smith, J. B. and W. A. Hubert. 1988. Growth, population structure and mortality of channel catfish from the Powder River and Crazy Woman Creek, Wyoming. The Prairie Naturalist 20:127–133.

Starkey, R. W. and D. L. Scarnecchia. 1999. Age and growth of channel catfish in the lower Yellowstone River, Montana. Intermountain Journal of Sciences 5:28–34.

Stash, S., R. G. White and D. B. Fuller. 2001. Distribution, relative abundance and habitat associations of Milk River fisheries related to irrigation diversion dams. United States Bureau of Reclamation, Billings, Montana.

United States Bureau of Reclamation. 1983. Milk River Project; Montana: Blaine, Glacier, Phillips and Valley Counties. Billings, Montana.

van Buuren, S. and K. Groothuis-Oudshoorn. 2011. mice: Multivariate Imputation by Chained Equations in R. Journal of Statistical Software 45:1–67.

Vokoun, J. C., T. L. Guerrant and C. F. Rabeni. 2003. Demographics and chronology of a spawning aggregation of blue sucker (*Cycleptus elongatus*) in the Grand River, Missouri, USA. Journal of Freshwater Ecology 18:567–575.

Walters, D. M., R. E. Zuellig, H. J. Crockett, J. F. Bruce, P. M. Lukacs and R. M. Fitzpatrick. 2014. Barriers impede upstream spawning migration of flathead chub. Transactions of the American Fisheries Society 143:17–25.

Watkins, C. J., B. S. Stevens, M. C. Quist, B. B. Shepard and S. C. Ireland. 2015. Patterns of fish assemblage structure and habitat use among main-and side-channel environments in the lower Kootenai River, Idaho. Transactions of the American Fisheries Society 144:1340–1355.

Western Regional Climate Center. 2001. Glasgow WB city, Montana. Desert Research Institute. Available: http://www.wrcc.dri.edu/. (June 2004).

White, R. G. and B. Mefford. 2002. Assessment of behavior and swimming ability of Yellowstone River sturgeon for design of fish passage devices. Unpublished report. Joint study by Montana State University in Bozeman, MT and Bureau of Reclamation Water Resources Research Laboratory in Denver, Colorado.

Wolfert, D. R. and T. J. Miller. 1978. Age, growth and food of northern pike in eastern Lake Ontario. Transactions of the American Fisheries Society 107:696–702.

Received 07 July 2016
Accepted 11 October 2016

Montana Chapter of The Wildlife Society

53nd Annual Meeting, 2016

Widlife Restoration Celebrating Conservation Success and Facing Future Challenges

February 23-26, 2016

Missoula, Montana

Mark Ruby, President 2016-17
Montana Chapter of The Wildlife Society

Introduction

This year's theme was Wildlife Restoration: *Celebrating Conservation Success and Facing Future Challenges*. The subject is one of the most challenging aspects of wildlife management. The focus is intentionally broad, as the success of conservation and management of our wildlife species is dependent on the synergy of many political, ecological, biological and social components that play a role in species conservation. There are many future challenges facing Montana's wildlife species such as a growing human population or a changing climate. To help build future solutions, we can keep an eye on past successes. We should do this not only to draw important lessons on science, management or policy from our peers or predecessors, but also to remind ourselves how much the future can benefit from the hard work of those that came before us.

The perspective from the past is an important one. We get to celebrate the conservation success of the agency biologists, university researchers and leaders that worked together to incorporate sound scientific management of wildlife to restore Montana's game populations in the early 1900s. Today we have a healthy population of wolves, compared to 30 years ago when managers questioned their presence at all. As we look to future challenges, our annual conference is a great forum to share experiences, collaborate and better define and learn how and where we can manage Montana's wildlife for future generations. About 350 wildlifers attended this year's conference.

The banquet speaker was Harold Picton, Emeritus Professor of Wildlife Management in the Department of Ecology at Montana State University. He is a charter member of the Chapter and served as its president in 1967. The title of his talk was, "The Pittman-Robertson Revolution: Skim Milk on the Hills, Drugs in the Swamp and Salting from the Air" It was received with a standing ovation.

Plenary Session Abstracts

In Order of Presenting Author

Restoring Wildlife Diverstiy at Landscape Scales

Jonathan Haufler, Ecosystem Management Research Institute, Seeley Lake, MT
Carolyn Mehl, Ecosystem Management Research Institute, Seeley Lake, MT

Maintaining and restoring biodiversity remains one of the most challenging objectives for natural resource managers. Wildlife biologists have primary responsibility for meeting these objectives. In the U.S., the Endangered Species Act has encouraged a species by species approach to biodiversity conservation. While managing listed species is an essential component of wildlife management, this is a reactive approach that kicks in only when a species is already on a downward spiral. Proactive planning and actions are needed to keep species from reaching such critical levels. This requires comprehensive and cohesive strategies for habitat diversity that will maintain sustainable populations of all species. Ecosystem-based approaches are a cornerstone to such strategies. Examples of applications of such approaches are presented including on-going ecosystem-based initiatives for grassland conservation using prairie grouse as flagship species and planning for future forest conditions using the ecological sustainability components of the USFS Forest Planning Rule. These approaches can provide the habitat diversity required to maintain biodiversity including conditions for species for which we have little information. Suggestions will be presented on how we can build support for these approaches including how we can encourage engagement of multiple agencies, NGO's, industries, and landowners in implementing needed conservation actions.

Lessons from Wolf Restoration in The Northwestern U.S.

Ed Bangs, Retired Wolf Recovery Coordinator, U.S. Fish and Wildlife Service, Helena, MT

Gray wolf (*Canis lupus*) populations were deliberately eliminated from nearly all of their historic range in the contiguous United States by 1930. Naturally dispersing wolves from Canada first denned in Montana in 1986. An intense period of scientific research, public outreach, and politics followed and resulted in wolves from western Canada being reintroduced to central Idaho and Yellowstone National Park, Wyoming in 1995 and 1996. The population grew rapidly and at least 1,600 wolves now live in Montana, Idaho, Wyoming, and parts of eastern Oregon and Washington (NRM). The population has been biologically recovered since December 2003 when at least 663 wolves were present but removal of federal protections was delayed for several years. Packs now occupy mountainous forested habitat in over 130,000 square miles of the NRM. Wolf restoration resulted in both benefits (public viewing, harvest opportunities, funding by tag sales, and restoration of ecological processes) and costs (agency funding, livestock and pet depredation, and competition with big game hunters). Federal, state, and tribal cooperators used a wide variety of deterrents, relocated wolves 117 times, and killed over 2,268 to reduce livestock conflicts. Wolves contributed to reducing some wild ungulate populations and harvest by hunters. Starting in 2009, states began to implement public harvest programs to provide hunter/trapper opportunity, reduce conflict, and meet other objectives. Up to one third of the minimum wolf population was legally killed by humans and as intended, it has helped stabilize the population and reduced conflicts. The NRM wolf population is now being managed similarly to other resident wildlife by the affected States (except Wyoming where litigation caused wolves to remain listed) and Native American Tribes. While the NRM wolf population is biologically healthy, controversy

continues as legal, policy, political, and human value issues continue to be debated symbolically through wolves. I discuss the history, science, and politics behind restoring wolves to the NRM and possible implications to future wolf restoration efforts.

Cultivating an Ecological and Cultural Paradigm Shift to Restore Bison on Large Prairie Landscapes

Keith E. Aune, Director of Bison Programs, The Wildlife Conservation Society, Bozeman, MT

The North American prairie was historically occupied by a wide assemblage of herbivores such as bison (*Bison bison*), elk (*Cervus elaphus*), deer (*Odocoileus* spp.) and pronghorn (*Antilocapra americana*) as well as a complementary suite of predators such as wolves (*Canis lupus*) and bears (*Ursus* spp.). Most prominent on the prairie grasslands was the enormous populations of bison that served as a keystone herbivore shaping the structure and composition of the prairie plant communities. In archeological sites throughout the plains bison remains dominate the faunal record (Fischer and Roll, 1999) and there is little doubt the modern version of this grazing bovid was ecologically important for 12,000 years. There is also little doubt that this large grazing bovid was of cultural significance to American Indian populations thriving on this ocean of grass for as long. In recent decades there has been a significant shift in thinking about the relative abundance, ecological role and cultural importance of bison on prairie landscapes of North America. With the decimation of bison in the late 19th century and the introduction of cattle the role of the most numerous native herbivore was diminished and replaced by a domestic bovid (Isenberg 2000). The disappearance of bison inspired much of our modern conservation ideals however bison were virtually absent as a free-ranging species as the conservation movement matured. Most early conservation thought and modern wildlife management theory developed after this grazing bovid was nearly extinct. Hence, the modern conservationists developed a keen sense for managing and restoring large numbers of cervid-like wildlife but had little experience with the most important native grazer present on the prairies for 12,000 years. Most prairie grasslands in North America have been managed during modern times to sustain bird populations and vast herds of free-roaming cervid- like animals such as mule deer, pronghorn and elk. Predators were mostly removed in the 19th Century to protect the favored game populations. Most of the early literature on population management of these wild prairie herbivores was based on the goal of producing a sustainable crop harvested annually by sportsmen. The emphasis was on gradualistic and incremental control of wild ungulate populations through annual harvest and habitat conservation to produce crops of game animals. This formed a modern traditional paradigm of wildlife management that has operated for many decades. In recent times conservation thought has shifted toward a more complete or holistic view of wild animals in natural environments. This paradigm shift has emphasized restoring the various roles and relationships of wildlife to create functional ecosystems. The management model has been slowly moving toward cultivation and protection of functional relationships between animals, plant communities and man instead of managing a standing crop. However, this paradigm shift has yet to fully embrace large scale restoration of one of the most significant native grazers and biological engineer of grassland ecosystems. For many, bison still remain a species replaceable and interchangeable with cattle or an extinct relic. Despite our growing knowledge of the ecological and cultural importance of bison there remains a reluctance to envision large scale bison restoration on grassland ecosystems.

Black-Footed Ferret Restoration; History, Challenges and Current Status

Randy Matchett, U.S. Fish and Wildlife Service, Charles M. Russell National Wildlife Refuge, Lewistown, MT

Black-footed ferrets (*Mustela nigripes*) were once found throughout the West on prairie dog (*Cynomys* spp.) colonies ranging from Canada to Mexico. Ferrets are totally dependent on prairie dogs as prey and for habitat, living exclusively in the burrow and tunnel systems created and maintained by prairie dogs. Cultivation of the Great Plains for crop production and prairie dog eradication efforts in support of domestic livestock production during the 20th century reduced black-tailed prairie dogs (*Cynomys ludovicianus*) by some 98% of their former extent and black-footed ferrets were thought extinct by the late 1970's. The surprise finding of a remnant population near Meeteetse Wyoming in 1981 gave new hope for survival of the species. However, devastating diseases resulted in a heroic rescue effort of remaining survivors and the beginnings of an intensive captive breeding effort. All black-footed ferrets in existence today are descendants of 7 founders from that effort. More than 8,500 ferrets have been born in captivity since 1985. The first reintroduction of black-footed ferrets back into the wild was in Shirley Basin, Wyoming in 1991. The first reintroduction in Montana was in 1994 on the UL Bend National Wildlife Refuge in north-central Montana. Notably, wolf reintroduction began 3 months after the first ferrets were released in Montana when wolves were placed in soft-release pens in Yellowstone National Park. More than 4,500 captive-reared black-footed ferrets have been released at 27 reintroduction sites since 1991. A total of about 300 black-footed ferrets were estimated alive in the wild at the end of 2015. Ferrets have been released at 5 sites in Montana; 3 on Indian Reservations (Fort Belknap, Northern Cheyenne and Crow), 1 on the UL Bend National Wildlife Refuge and 1 on Bureau of Land Management lands that are part of The Nature Conservancy's Matador Ranch. There are numerous challenges to recovery of this critically endangered species. Understanding and attempting to manage sylvatic plague, an exotic disease introduced to North America in the early 1900's, is foremost on the research front and a formidable biological challenge. There are both promising and challenging aspects to plague management. Social tolerance of prairie dogs on the landscape by agricultural interests and some natural resource managers is also a significant obstacle to black-footed ferret recovery. Opportunities are available to develop locales capable of supporting ferret populations if the right synergies of social and biological interactions can be fostered. Despite highly varied and emotional viewpoints, along with intense controversy, Montanan's have found room for wolves as native fauna and they now occupy more than one-third of the state. Hopefully, Montanan's can also find room for a few thousand acres of prairie dogs in multiple places that can each support viable ferret populations. Recovering an endangered species that was once thought extinct, and one that is truly indicative of prairie ecosystem function and health, would be an accomplishment. However, continuing investment in recovery of this species in the wild has been, understandably, criticized. Until recovery of black-footed ferrets is no longer deemed a worthy pursuit, efforts to provide a landscape that could support prairie dogs, ferrets and other native wildlife that were once widespread across the Great Plains will continue.

Presentation Abstracts

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

Spatial and Temporal Patterns of Trichinella in Montana's Black Bears, 2004-2014

Emily Almberg*, Wildlife Health Laboratory, Montana Fish, Wildlife, and Parks, Bozeman
Lynnzie Tompkins, Department of Biotechnology, Montana State University, Bozeman
Floyd Seesee, Department of Veterinary Science, Montana State University, Bozeman
Jennifer Ramsey, Wildlife Health Laboratory, Montana Fish, Wildlife, and Parks, Bozeman
Keri Carson, Wildlife Health Laboratory, Montana Fish, Wildlife, and Parks, Bozeman
Neil Anderson, Montana Fish, Wildlife, and Parks, Kalispell

Trichinella nematodes are a globally distributed, zoonotic parasite transmitted through the consumption of infected animal tissue. Humans are at risk of contracting Trichinella by consuming undercooked bear or mountain lion meat, and thus historically, Montana Fish, Wildlife, and Parks subsidized Trichinella-testing of hunter-harvested black bears (*Ursus americanus*) and mountain lions (*Puma concolor*). Here, we summarize 11 years of data (2004-2014) on the spatial and temporal distribution of Trichinella in Montana's black bears. Risk of infection was spatially variable, highest in northwest Regions 1 and 4, and was positively associated with black bear and grizzly bear (*Ursus arctos horrobilis*) densities. Prevalence has been significantly declining across the state over time from a state-wide prevalence of 0.05 in 2004 to 0.02 in 2014. Potential causes and consequences are discussed. Montana Fish, Wildlife, and Parks stopped subsidizing Trichinella testing in 2015; hunters are asked to thoroughly cook their meat to an internal temperature of 165° F, which inactivates Trichinella species and most other parasites.

A Comparison of Occupied and Unoccupied Sharp-Tailed Grouse Habitat in Montana

Alissa A. Anderson*, Wildlife Division, Montana Fish, Wildlife and Parks, Kalispell
Kaitlyn E. Farrar*, Wildlife Division, Montana Fish, Wildlife and Parks, Kalispell

The sharp-tailed grouse (*Tympanuchus phasianellus*) was once present throughout the state of Montana. The species was extirpated in Montana west of the Continental Divide by the late 2000's, while healthy populations still exist east of the Continental Divide. We compared key habitat components important to sharp-tailed grouse survival in occupied areas east of the Divide to unoccupied areas west of the Divide. We measured vegetative variables related to nesting, brood-rearing, and wintering habitat requirements in 3 occupied study areas and 4 unoccupied study areas during the spring of 2015. Habitat Suitability Index scores were calculated for nesting and brood-rearing. Habitat Suitability Index averages show habitat in the Blackfoot valley to be most suitable for sustaining a sharp-tailed grouse population, habitat in the Bitterroot valley to be potentially suitable, and habitat in Drummond and in the Mission Valley to be unsuitable at this time. These results suggest that the Blackfoot and Bitterroot valleys may contain suitable habitat for a potential sharp-tailed grouse reintroduction.

**Wolf Pack Distribution in Relation to Heavy Harvest in Southwest Alberta

Sarah B. Bassing*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Michael S. Mitchell, U.S. Geological Survey, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Paul M. Lukacs, Wildlife Biology Program, University of Montana, Missoula
Dave E. Ausband, Idaho Department of Fish & Game, Coeur d'Alene
Lisette P. Waits, Department of Fish & Wildlife Sciences, University of Idaho, Moscow
Greg Hale, Fish & Wildlife, Alberta Environmental & Sustainable Resource Development, Blairmore

Gray wolf (*Canis lupus*) populations are difficult to monitor because wolves can be elusive and occur in low densities. Harvest can further complicate wolf monitoring by affecting wolf behavior, altering pack structure, and potentially reducing probability of detection. Currently, Montana and Idaho use patch occupancy models to monitor wolves at state-wide scales. These models were originally developed prior to the initiation of wolf harvest and there is growing concern that current occupancy estimates are becoming less reliable as harvest continues. Our objectives were to determine whether we could estimate wolf distribution for a heavily harvested wolf population and assess how harvest may be affecting that distribution. We surveyed potential rendezvous sites and collected DNA samples from wolf scats for genetic analysis and surveyed hunters for wolf sightings in southwestern Alberta from 2012 to 2014. We used a Bayesian approach to fit dynamic occupancy models to the encounter histories while accounting for false-positive detections using JAGS and Program R. We found both habitat and anthropogenic factors influenced wolf occupancy parameters in southwestern Alberta and detection probability varied by survey method. Our preliminary results suggest wolf pack distribution is fairly consistent but that source-sink dynamics may be occurring in certain regions of the study area. Despite heavy harvest pressure, southwestern Alberta appears to maintain a stable wolf population, although this is possibly due to immigration from nearby regions.

Effects of Wolf Removal on Livestock Depredation Recurrence and Wolf Recovery in Montana, Idaho and Wyoming

Elizabeth H. Bradley,* Montana Fish, Wildlife and Parks, Missoula
Hugh S. Robinson, University of Montana, Missoula
Edward E. Bangs, U.S. Fish and Wildlife Service, Helena, MT
Kyran Kunkel, University of Montana, Missoula
Michael D. Jimenez, U.S. Fish and Wildlife Service, Jackson, WY
Justin A. Gude, Montana Fish, Wildlife and Parks, Helena
Todd Grimm, U.S. Department of Agriculture Wildlife Services, Boise, ID

Wolf predation on livestock and management methods used to mitigate conflicts are highly controversial and scrutinized especially where wolf populations are recovering. Wolves are commonly removed from a local area in attempts to reduce further depredations, but the effectiveness of such management actions is poorly understood. We compared the effects of 3 management responses to livestock depredation by wolf packs in Montana, Idaho, and Wyoming: no removal, partial pack removal, and full pack removal. From 1989 to 2008, we documented 967 depredations by 156 packs: 228 on sheep and 739 on cattle and other stock. Median time between recurrent depredations was 19 days following no removal (n = 593), 64 days following partial pack removal (n = 326), and 730 days following full pack

removal (n = 48). Partial pack removal was most effective if conducted within the first 7 days following depredation, after which there was only a marginally significant difference between partial pack removal and no action (HR = 0.86, P = 0.07), and no difference after 14 days (HR = 0.99, P = 0.93). Ultimately, pack size was the best predictor of a recurrent depredation event; the probability of a depredation event recurring within 5 years increased by 7% for each animal left in the pack after the management response. However, the greater the number of wolves left in a pack, the higher the likelihood the pack met federal criteria to count as a breeding pair the following year toward population recovery goals.

**What Does it all Mean? Interpreting Respiratory Pathogen Survey Results for Bighorn Sheep Management

Carson J. Butler *, Ecology Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman

Respiratory disease has been a major challenge for bighorn sheep (*Ovis canadensis*) conservation and is a dominant factor influencing management decisions of bighorn sheep, however; much about the disease process remains unknown. Decades of research have compiled considerable evidence that domestic sheep and goats can transmit the disease to bighorn sheep as well as strong evidence for several bacterial organisms as causative agents for the disease. However, there are examples of bighorn populations hosting the agents linked to respiratory disease with little demographic side-effects. Further, the immediate cause of disease events often remains undetermined. Two general hypotheses exist to explain observed disease events in wildlife populations: 1) A disease event is caused by introduction of a novel pathogen from neighboring or sympatric host populations or; 2) A disease event is caused by certain conditions triggering endemic pathogens to become virulent to the host. While the extent to which these competing hypotheses explain observed respiratory disease events in bighorn sheep is unknown, the appropriate management actions to address disease due to these different processes are very different. Effectively addressing these hypotheses and better understanding the major causes of observed respiratory disease events is a challenge and requires rigorous and repeated pathogen sampling in bighorn populations both affected and seemingly unaffected by respiratory disease. This presentation provides a brief background of bighorn respiratory disease, highlights the challenges of interpreting respiratory pathogen survey results to inform management as well as recent advances in respiratory pathogen research that have promise to help further inform management decisions.

25 Years Of Aspen Wildlife Habitat Restoration on the Beartooth Ranger District, Custer Gallatin National Forest

Jodie E. Canfield*, Custer Gallatin National Forest, Bozeman, MT
Shawn Stewart, Montana Fish Wildlife and Parks, Red Lodge

Aspen (*Populus tremuloides*) is one of the most biologically diverse ecosystems in the Intermountain West. Aspen is an important wildlife habitat, providing forage, cover, shade, and nesting for birds, small mammals, big game, and forest carnivores. Upland game birds, particularly ruffed grouse (*Bonasa umbellus*), are associated with aspen. Ruffed grouse are a habitat indicator species for aspen communities in the Custer National Forest Plan. Montana's Comprehensive Fish and Wildlife Conservation Strategy (2005) identified aspen as a community type of greatest conservation need due to altered natural fire regimes. Although aspen is a rare vegetation component on the Custer Gallatin National Forest, the Beartooth

Ranger District supports relatively large expanses of aspen along the Beartooth Mountain Face. Many of these aspen communities had converted to conifers, or were declining in health. In recognition of this opportunity to restore wildlife habitat, a management plan was developed in 1990, featuring ruffed grouse. Since 1990, crews have treated about 141 aspen stands on about 400 acres. Methods included prescribed burning and using chainsaws and other hand tools, resulting in the creation of a mosaic of aspen size and age classes and drumming logs that fulfill the yearlong habitat needs of ruffed grouse. Funding for these treatments came largely from a partnership between the Beartooth Ranger District and Montana's Upland Bird Program. Wildlife observed using treated aspen stands included a diverse array of cavity and non-cavity nesting birds, including ruffed grouse, small mammals and big game, especially moose (*Alces alces*).

2015 Wildlife Disease Retrospective

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

Montana Fish, Wildlife and Parks is developing a Wildlife Health Program. One of the functions of the program is to integrate disease surveillance, population health monitoring, and wildlife health diagnostic services to provide information to the public and wildlife professionals on the dynamics, risk, and impacts of disease in Montana's wildlife. The knowledge gained from this program is aimed at improving conservation efforts and the safety of both humans and domestic animals. The Wildlife Health Laboratory is a statewide lab that receives hundreds to thousands of biological samples each year for disease surveillance projects, epidemiologic and morbidity investigations, and forensics. An overview of notable zoonotic and non-zoonotic diseases detected from 2015 laboratory submissions will be discussed, providing relevance, repercussions and general background or recent history of the disease in Montana.

Brown Bear and Human Recreational Use of Trails in Anchorage, Alaska

Jessica A. Coltrane*, Montana Fish Wildlife & Parks, Kalispell
Rick Sinnott, retired, Alaska Department of Fish and Game, Anchorage

The Municipality of Anchorage, Alaska, has 301,000 human residents and hundreds of thousands of visitors each year. Anchorage also supports a viable population of brown bears (*Ursus arctos alascensis*). As a result, human-bear encounters are common. We monitored recreational trails near salmon spawning streams at 3 study sites with camera traps during the summers of 2009 – 2012 to better understand daily and seasonal activity patterns of bears and humans on these trails. We found that the more remote study sites had the least human activity and the most bear activity, and human-bear encounters were most likely to occur from July through early September due to a higher degree of overlap between human and bear activity during this timeframe. Most brown bears at our study sites appeared to have adopted a crepuscular and nocturnal activity pattern, which was more pronounced at the site with the most human use. More people used trails Friday through Sunday, while there was no difference in bear activity among days of week. Recreational activities and user groups differed among sites. Based on our data, areas should be assessed individually to mitigate adverse human-bear encounters. However, one potential solution for avoiding dangerous bear encounters at all study sites is to restrict human access or types of recreational activity. When human access is controlled in important bear habitat, distribution of visitors becomes spatially

and temporally more predictable, allowing bears an opportunity to adjust activity patterns to avoid people while still using the resource.

Estimation of Sustainable Mortality Thresholds for Grizzly Bears in the Northern Continental Divide Ecosystem

Cecily M. Costello*, Montana Fish, Wildlife, and Parks, Kalispell
Richard D. Mace, Montana Fish, Wildlife, and Parks, Kalispell
Lori Roberts, Montana Fish, Wildlife, and Parks, Kalispell
Daniel Carney, Blackfeet Fish and Wildlife Department, Browning, MT
Stacy Courville, Confederated Salish and Kootenai Tribe, East Polson, MT
James Jonkel, Montana Fish, Wildlife and Parks, Missoula
Michael Madel, Montana Fish, Wildlife and Parks, Choteau
Tim Manley, Montana Fish, Wildlife and Parks, Kalispell
John Waller, National Park Service, Glacier National Park, West Glacier
Erik Wenum, Montana Fish, Wildlife and Parks, Kalispell

Habitat management and limits on mortality have led to population growth and sizable range expansion for the federally-listed grizzly bear population in the Northern Continental Divide Ecosystem (NCDE), Montana. Human-caused mortality has coincidentally increased, but it is not clear what level of human-caused mortality would cause the population to decline. A record of annual documented mortalities of independent (≥2 years old) bears is maintained for the NCDE, from which an estimate of the total number of mortalities is generated. Our goal was to estimate sustainable survival rates for independent bears and to develop realistic thresholds for sustainable mortality, which could be applied to these annual estimates. We estimated survival and recruitment rates using 662 bear-years of telemetry data, performed stochastic modeling, and estimated the annual growth rate as 1.023 and annual population size as 765–960 during 2004–2014. We then evaluated minimum independent survival rates consistent with a stable to increasing trend, and integrated these sustainable rates with model-estimated population size and mean estimates of total annual independent bear mortality to establish mortality thresholds. During 2004–2014, estimates of total annual mortality were highly variable, but averaged 13.8 for females and 16.4 for males. For females and males, respectively, these estimates accounted for only 69% (range 28–168%) and 62% (28–121%) of sustainable mortality thresholds, indicating that approximately 6 and 10 additional annual mortalities could have been sustained without the population declining. Application and periodic reevaluation of mortality thresholds will help managers reach or maintain a target population size for grizzly bears in the NCDE.

Estimating Survival and Determining Causes of Mortality of Golden Eagles in South-Central Montana

Ross Crandall*, Craighead Beringia South, Kelly, WY
Derek Craighead, Craighead Beringia South, Kelly, WY
Bryan Bedrosian, Teton Raptor Center, Jackson, WY

There is concern for golden eagles (*Aquilla chrysaetos*) in the West as a result of contradictory population trend estimates and a likely increase in threats including but not limited to expanded wind energy development. Estimating survival of golden eagles and identifying causes of mortality can be used to assess the viability of nesting golden eagle populations and to direct mitigation efforts if necessary. To date, little information exists on golden eagle survival in western North America. In addition, identified causes of golden eagle mortality are often associated with an opportunity to find dead birds, creating a potential

bias that may be minimized with the use of satellite telemetry. We outfitted 17 adult and 13 nestling golden eagles with satellite transmitters during the 2011-2014 nesting seasons near Livingston, Montana to estimate survival and determine causes of mortality. We used multi-state models to estimate survival over discrete-time periods for both adults and nestlings. Preliminary results showed our survival estimates were consistent with similar long-lived, slow reproducing raptors. Golden eagle mortalities in our study were a result of poisoning, intraspecific interaction and poaching. Our survival estimates are consistent with the stable density of breeding golden eagles in our study area and the primary causes of mortality differed from repository-based studies.

Evaluating Success for a Within-Mountain Range Transplant of Bighorn Sheep in Southwestern Montana

Julie Cunningham*, Montana Fish, Wildlife and Parks, Bozeman
Howard Burt, Montana Fish, Wildlife and Parks, Bozeman
Robert Garrott, Montana State University, Bozeman
Kelly Proffitt, Montana Fish, Wildlife and Parks, Bozeman
Quentin Kujala, Montana Fish, Wildlife and Parks, Helena
Jennifer Ramsey, Montana Fish, Wildlife and Parks, Bozeman
Cheyenne Stirling, Montana State University, Bozeman
Carson Butler, Montana State University, Bozeman
Keri Carson, Montana Fish, Wildlife and Parks, Bozeman

Montana Fish, Wildlife and Parks (MFWP) performed a bighorn sheep (*Ovis canadensis*) transplant within the Madison Mountains of southwest Montana February 2015. Once with 5 distinct wintering ranges, the herd since endured, and recovered from, several all-age die-offs. As of 2013, one historic wintering area was overpopulated (>250 bighorn), one sparsely populated (~30 bighorn), and three historic wintering areas were left unoccupied: Indian Creek, Wolf Creek, and the Henry's Mountains. MFWP evaluated habitat and proposed to reintroduce bighorn from the overpopulated wintering range to either Wolf Creek or Indian Creek. After the EA and public process concluded, Wolf Creek was the selected release site. MFWP captured 52 bighorn from the overpopulated winter range using a drop-net, and moved them via trailer to the release site. Ten of the released bighorns were fitted with LOTEK Lifecycle GPS collars, providing satellite location data once daily for up to 4 years. Transplant success was mixed, with three collared bighorns immediately returning to their former range, three collared bighorns wintering at the sparsely populated intermediate range, and four collared bighorns remaining through winter and into summer at the reintroduction site. One bighorn died shortly after release. The four collared bighorns remaining at the release site explored Indian Creek through summer, then in July, 3 returned to their original range and 1 remained in the transplant area. Of the 52 bighorns transplanted, approximately 10-15 remain in the Wolf Creek transplant range. Subsequent transplants are planned to enhance the restoration of bighorn sheep in the Madison Range.

**Kodiak Brown Bears Surf the Salmon Red Wave: Direct Evidence from GPS Collared Individuals

William W. Deacy*, Flathead Lake Biological Station, University of Montana, Polson
William B. Leacock, Kodiak National Wildlife Refuge, Kodiak, AK
Jonathan B. Armstrong, Oregon State University, Corvallis
Jack A. Stanford, Flathead Lake Biological Station, University of Montana, Polson

One of the goals of Ecosystems Base Fisheries Management (EBFM) is recognizing and mitigating indirect effects of fisheries on trophic interactions. Most research on indirect effects has considered how the abundance of managed fishes influences trophic interactions with other species. However, recent work has shown that attributes besides abundance, such as life history variation, can strongly mediate species interactions. For example, phenological variation within prey species may enhance foraging opportunities for mobile predators by increasing the duration over which predators can target vulnerable life stages of prey. Here, we present direct evidence of individual brown bears (*Ursus arctos middendorffi*) exploiting variation in sockeye salmon spawning phenology by tracking salmon runs across a 2,800 km^2 region of Kodiak Island. Data from 40 GPS collared brown bears show bears visited multiple spawning sites in synchrony with the order of spawning phenology. The average time spent feeding on salmon was 67 days, while the average duration of spawning for one population was only 40 days. The number of sites used was correlated with the number of days a bear exploited salmon, suggesting phenological variation in the study area influenced bear access to salmon, a resource which strongly influences bear fitness. These results suggest fisheries managers attempting to maximize harvest while minimizing impacts on brown bears should strive to protect the population diversity that underlies the phenological variation used by wildlife consumers. These results underscore the need to understand how fisheries affect life history diversity in addition to abundance in order to minimize negative effects of fisheries management on non-target species, a goal of EBFM.

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

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

Since the mid-to-late 1990s, lesser scaup (*Aythya affinis*) populations have remained more than 20% below the population goal set forth in the North American Waterfowl Management Plan. Accordingly, considerable attention has been directed towards understanding what factors may be limiting their population, including the role of harvest. Red Rock Lakes National Wildlife Refuge (RRL) in southwestern Montana is the site of a long-term study of lesser scaup ecology and demography. Preliminary harvest estimates indicate that this population is harvested at rates similar to the continental population with juveniles experiencing an annual average harvest rate of 9.1% (95% CI = 7.7 - 10.7%) and adults an average annual harvest rate of 3.6% (95% CI = 2.2 - 6.1%). Since 2005, ~1,300 female have been banded on the study site and an additional ~1,000 females have been nasal-marked. In addition, ~1,400 resightings have been collected for nasal-marked hens on the study site and ~340 dead recoveries from our study population have been reported from Canada to Mexico. With results obtained from multistrata models that utilize these multiple encounter types, I will present (1) estimates of harvest and natural mortality rates for female lesser scaup banded

and nasal-marked at RRL from 2005-2016; (2) how non-harvest mortality varies in relation to harvest mortality over the same period; (3) an assessment of how these rates respond to changes in hunting regulations. These results will be used to help inform lesser scaup harvest demography, a key structural uncertainty in current harvest models identified in the draft Scaup Conservation Action Plan.

Wolf-Livestock Conflict in Montana: Spatial and Temporal Factors Influencing Livestock Loss

Nicholas J. DeCesare*, Montana Fish, Wildlife and Parks, Missoula
Elizabeth H. Bradley, Montana Fish, Wildlife and Parks, Missoula
Justin A. Gude, Montana Fish, Wildlife and Parks, Helena
Nathan Lance, Montana Fish, Wildlife and Parks, Butte
Kent Laudon, US Fish and Wildlife Service, Alpine, AZ
Abigail Nelson, Montana Fish, Wildlife and Parks, Livingston
Mike Ross, Montana Fish, Wildlife and Parks, Bozeman
Ty Smucker, Montana Fish, Wildlife and Parks, Great Falls
Seth Wilson, Montana Livestock Loss Board, Northern Rockies Conservation Cooperative, Missoula

Successful wolf (*Canis lupus*) recovery in Montana has brought with it some negative impacts on livestock producers in certain areas and time periods. We assessed the spatial and temporal patterns of wolf depredations on livestock in Montana at a broad, statewide scale during the past decade (2005–2014). These analyses highlighted areas of concentrated and consistent wolf-livestock conflicts, such that, for example, 50% of the statewide conflicts occur in 5% of the state. We then used generalized linear mixed-models to test covariates potentially predictive of both conflict presence (zero vs. non-zero depredation events) and conflict severity (number of events given at least 1), including the assessment of lethal controls and hunter harvest as tools to reduce conflicts. Using administrative hunting districts (HDs) as the unit of analysis, we found that conflict presence increased for HD-years with wolves present ($P<0.001$), higher wolf pack densities ($P=0.006$), higher livestock densities ($P<0.001$), and intermediate proportionate areas of agricultural land ($P<0.001$). HDs with depredations the previous year were more likely to continue having them ($P<0.001$), though lethal removal of wolves significantly reduced this effect ($P=0.038$). Direct effects of wolf hunter harvest were shown to marginally ($P=0.152$) reduce year-to-year conflicts, but indirect effects of harvest would also be expected given its role in determining wolf numbers, a primary driver of conflicts. Minimizing livestock losses is a top priority for successful wolf management, and these results shed light on the broad-scale patterns behind chronic problems and the tools used to address them.

Wing-Tagged Encounters of Golden Eagles Captured in Montana

Robert Domench*, Raptor View Research Inst., P.O. Box 4323, Missoula
Adam Shreading, Raptor View Research Inst., P.O. Box 4323, Missoula
Bracken Brown, Raptor View Research Inst., P.O. Box 4323, Missoula

Recently, there has been an increase in concern for Golden Eagle (*Aquila chrysaetos*) populations in the western U.S. The concern stems from a marked decrease in the number of migrants and future threats from a variety of anthropogenic factors including industrial energy development. Thus, there is a need for more information on Golden Eagles including: where they winter, longevity, causes of mortality and critical habitat needs. Standard banding offers

low encounter rates (ca. 7%) and satellite telemetry is cost prohibitive for large sample sizes. We began auxiliary marking Golden Eagles with vinyl wing-tag markers as a cost effective means to gather information on the species. Since 2004, we have wing-tagged 260 eagles, and re-encountered 59 individuals, giving us a 23% encounter rate. This technique is proving considerably more effective than banding alone as a means of identifying individuals and receiving re-encounter information. We attribute this success, in part, to internet information sharing and the increasing use of remote cameras set up on carcasses to view scavenger activity. Given our observed encounter rates, we suggest utilizing wing-tags as a form of auxiliary marking to augment studies where standard banding is the lone marking method.

Effectiveness of Trail Cameras and Scat Genetics for Detecting Northern Bog Lemmings in Western Montana

Kristi DuBois*, Montana Fish, Wildlife & Parks, Missoula

The northern bog lemming (*Synaptomys borealis*) is a boreal species that extends south into Washington, Idaho, and Montana in the west. Little is known about this rare species in Montana, in part due to the difficulty of catching it using standard small mammal trapping methods. Prior surveys with Sherman live traps resulted in low trapping success and high mortality rates for northern bog lemmings. This species is currently being evaluated for ESA listing, so better methods for detecting them are needed. We tested scat boards and Bushnell NatureView trail cameras with close-up lenses to determine their effectiveness for detecting northern bog lemmings. Cameras were pointed at scat boards baited with muskrat lure. In 2015 we surveyed seven wetland sites, five of which were known northern bog lemming sites, for 3- 8 nights each with 5-10 cameras per site. Camera-nights at each site ranged from 15 to 38, and totaled 188 camera-nights overall. We obtained definitive and probable detections of northern bog lemmings (n=8) at three sites for a detection rate of 4.25 detections per 100 camera-nights. Twenty scat samples collected from scat boards, runways, and latrine sites were submitted to the National Genomics Laboratory for Wildlife and Fish Conservation at the Rocky Mountain Research Station in Missoula. Genetic testing is in progress to determine species identification (results will be presented, if available). Trail cameras are easy to deploy and less labor-intensive than live trapping for detecting small mammal species that can be identified from photographs. Efficiency may be improved by finding better lures, but overall, species identification through genetic analysis of scat would be the most cost effective way to survey northern bog lemmings, if it is proven to work.

**Investigating the Effects of Bison Grazing on Grassland Songbirds

Danielle A. Fagre*, Avian Science Center, University of Montana, Missoula
Victoria J. Dreitz, Avian Science Center, University of Montana, Missoula

The National Bison Range (NBR) in the Mission Valley of Montana manages a herd of 325-350 bison (*Bison bison*). Bison are rotated through eight grazing pastures, which consist mostly of intermountain grassland. This creates different grazing intensities, based on length of time grazed, season grazed, and density of bison. Grazing is considered to be an important source of disturbance in grassland systems. However, different grazing intensities may create more or less favorable conditions for grassland breeding songbirds, a suite of birds that has declined drastically over the last few decades. This research investigates the interaction between bison grazing and songbird abundance. We used double-dependent observer transects to record grassland songbird observations during the pilot season of 2015. We present preliminary results from the pilot season of grassland songbird abundance and density. The

outcomes will culminate into a concrete, local monitoring program for the NBR to support conservation of grassland songbirds, and will allow them to adjust management activities to maintain suitable grassland songbird habitat. Furthermore, the research will illuminate the relationship between a native grazer and grassland birds. While domestic livestock have largely replaced native grazers on grasslands, numerous reintroduction efforts of bison have been proposed. This study will help inform the expected outcomes and management objectives of those reintroduction efforts.

Is Fall Green-Up Significant?

Phillip Farnes*, Snowcap Hydrology, Bozeman, MT

Fall green-up does not occur every year. Methods have been developed to determine whether or not fall green-up occurs at each SNOTEL and Climatological site in the Greater Yellowstone area. It is based on climatic conditions after the first killing frost (daily Tmin of 22^0 F or less) and growing degree days and precipitation that occur after that point. Green-up vegetation may be available into January or February if snow covers the vegetation before another Tmin of 22^0 F or lower occurs. Crude protein of cured grasses is about 3 to 7 percent. Ungulates need crude protein of about 6-8 percent in order to maintain fat reserves. Green vegetation has a crude protein of about 10 to 13 percent. Years with no fall green-up can make winter survival difficult for males, especially bull elk trying to recover from the rut. Winters that are more severe can further affect survival. Predators may capitalize on animals in poorer physical condition. Methods and procedures used to determine which years fall green-up occurs will be presented and possible impacts of fall green-up will be discussed.

**An Initial Assessment of the Potential of Genomic Analysis to Help Inform Bighorn Sheep Management

Elizabeth P. Flesch*, Animal & Range Sciences Department, Montana State University, Bozeman
Jennifer M. Thomson, Animal and Range Sciences Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman
Tabitha A. Graves, Northern Rocky Mountain Science Center, USGS, West Glacier, MT

Genetic research may be a useful approach for understanding factors that could impact productivity and restoration of bighorn sheep (*Ovis canadensis*) herds. For example, genetic consequences of inbreeding in small populations can impact recruitment and local adaptations can influence translocation success. This modest pilot study quantified genetic attributes of bighorn sheep populations with a range of different herd histories in Montana and Wyoming to investigate genetic similarity and differences, genetic heterogeneity and genetic distance. Employing an Ovine array containing about 700,000 single nucleotide polymorphisms (SNPs) with approximately 24,000 markers that are informative for Rocky Mountain bighorn sheep, we used whole genome genotyping to analyze genetic material. This technique represents a significant advancement in genetic analysis of bighorn sheep, as most previous studies have used microsatellites and less than 200 genetic markers. We analyzed approximately fifteen individuals from each of four different populations that we predicted would differ in genetic characteristics, due to population dissimilarities that potentially impacted their genetics, including origin (native/reintroduced), population size, bottleneck history, degree of connectivity, and augmentation history. We selected four populations that provided a spectrum of these herd attributes, including the Tendoys, Stillwater and Glacier National Park in Montana and the northeastern Greater Yellowstone Area in Wyoming. We present the results of this effort and examine expected and observed heterogeneity and genetic distance

estimates to evaluate the potential for links between genetics and herd demography. We discuss the utility of genetic analyses in improving knowledge of bighorn sheep populations and potential implications for bighorn sheep management.

Assessing Grazing as a Conservation Tool in Sagebrush and Grassland Ecosystems

Jessie Golding*, University of Montana, Avian Science Center, Missoula
Victoria J. Dreitz, University of Montana, Avian Science Center, Missoula

Grazing is a powerful tool to address wildlife declines associated with land use conversion in the western United States. Grazing systems can be manipulated to achieve desired vegetation outcomes, preserve native habitat and economically benefit multiple stakeholders. As a result, systems designed to benefit native ecosystems are being widely implemented. However, the benefits of these grazing systems on many wildlife communities remain relatively unexplored. Songbirds provide an ideal study system to test these benefits because they continue to use landscapes that are currently grazed. We compared songbird communities between two grazing systems in eastern Montana: rest-rotation systems and season-long systems. Our results suggest grassland and sagebrush (*Artemsia* spp.) associated species, many of which are of conservation concern, exhibit a mixed response to these two grazing types. Grassland associated species are more abundant in season-long grazing systems than rest-rotation grazing systems. In contrast, sagebrush associated species show no difference in abundance between the two grazing systems. These results suggest that grazing management may have the largest impact on grassland associated species. In contrast to the idea that different grazing management can have effects on a wide variety species with similar life history traits, such as birds, we found that differences in grazing management only affected a small subset of species. Our findings provide essential information for assessing the suitability of grazing as a conservation tool.

**Pregnancy Rates, Metabolites and Metabolic Hormones in Bighorn Sheep During and After the Breeding Season

M. Rashelle Herrygers*, Department of Animal and Range Sciences, Montana State University, Bozeman
Jesse R. White, Department of Animal and Range Sciences, Montana State University, Bozeman
Jennifer M. Thomson, Department of Animal and Range Sciences, Montana State University, Bozeman
Carson J. Butler, Ecology Department, Montana State University, Bozeman
Douglas E. McWhirter, Wyoming Game and Fish Department, Cody
William H. Edwards, Wyoming Game and Fish Department, Laramie
Kevin Monteith, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie
Robert A. Garrott, Ecology Department, Montana State University, Bozeman
James G. Berardinelli, Department of Animal and Range Sciences, Montana State University, Bozeman

Wildlife managers routinely draw blood and harvest serum when bighorn sheep (*Ovis canadensis*) and other ungulates are captured for management and research purposes. Serum samples are routinely submitted to state livestock labs that perform a panel of assays to access exposure to a variety of important pathogens that cause disease, providing managers important insights. Wildlife managers would also benefit from similar procedures that could provide assessments of reproduction, nutrition, and physiological status. The objectives

of this preliminary study were to evaluate pregnancy rates, energy-related metabolites and hormones among herds of Montana and Wyoming bighorn sheep during and after the breeding season in order to assess the general 'health' of herds. Metabolites and metabolic hormones are frequently used in domestic animals to evaluate nutrition, reproduction and energy balance, and potentially may provide the same insights in wildlife for managers. A total of 240 bighorn ewes were sampled from 13 herds between December 2014 and March 2015. Samples were assayed for progesterone (P4) and pregnancy specific protein B (PSPBs) to assess reproductive cycling and pregnancy. Assays were also performed for non-esterified fatty acid, insulin, triiodothyronine and thyroxine which are metabolites and metabolic hormones that indicate nutritional and energy states of animals. We will be presenting the results of this preliminary study and discussing the relationship between pregnancy rates, energy-related metabolites and hormones and how they might be used to inform wildlife management.

Occupancy and Abundance of American Badgers and Piute Ground Squirrels in the Sagebrush-Steppe: Implications of the Fire-Cheatgrass Cycle

Joseph Holbrook*, U.S. Forest Service, Rocky Mountain Research Station, Missoula, MT
Robert Arkle, U.S. Geological Survey, Boise, ID
Kerri Vierling, Department of Fish and Wildlife Sciences, University of Idaho, Moscow
Janet Rachlow, Department of Fish and Wildlife Sciences, University of Idaho, Moscow
David Pilliod, U.S. Geological Survey, Boise, ID
Michelle Wiest, Department of Statistical Science, University of Idaho, Moscow

Sagebrush-steppe is experiencing vast changes due to biological invasions and changing fire characteristics. Understanding how these changes influence functionally important animals is essential for ecosystem management. American Badgers (*Taxidea taxus*) are an apex predator and ecosystem engineer within sagebrush ecosystems. Piute Ground Squirrels (*Urocitellus mollis*) are also an ecosystem engineer as well as an essential prey source for many predators. Our objective was to evaluate the relative importance of large-scale changes, abiotic processes, and biotic processes on badgers and ground squirrels. We samples 163 1-ha plots across a gradient of burn histories within a 1,962 km^2 area in Southern Idaho, USA. At each plot, we characterized ground squirrel and badger occupancy, ground squirrel relative abundance, and many environmental variables. We used information-theoretic approaches to evaluate competing hypotheses concerning occupancy of ground squirrels and badgers, and ground squirrel relative abundance. Results suggest that ground squirrel occupancy was positively associated with abiotic characteristics (e.g., higher precipitation and finer textured soil). Badger occupancy was positively associated with ground squirrel occupancy and agriculture. Relative abundance of ground squirrels was positively associated with finer textured soils, but negatively associated with cheatgrass (*Bromus tectorum*), fire frequency, agriculture and shrubs. Managers can focus restoration efforts on areas with high cheatgrass and shrub cover, if ground squirrels are a management objective. These results support previous hypotheses suggesting abiotic processes are important for herbivore occupancy. However, we provide support that a combination of abiotic, biotic and disturbance processes are important for mesocarnivore occupancy and herbivore abundance.

Factors Influencing Seasonal Migrations of Pronghorn Across the Northern Sagebrush Steppe

Andrew F. Jakes*, Faculty of Environmental Design, University of Calgary, Alberta

Globally, grassland systems have received the highest impacts from human activities, and therefore management of these systems is important for ungulate conservation. Pronghorn (*Antilocapra americana*) undertake seasonal migrations to satisfy annual life history requirements. The effects from environmental gradients and anthropogenic factors on pronghorn migrations are not well understood. My objectives were to: 1) Classify and determine metrics for various movement behaviors and states across individuals; 2) Predict multi-scale seasonal pronghorn migration pathways across the Northern Sagebrush Steppe (NSS) and integrate scales into one spatial prediction and; 3) Create pronghorn connectivity network maps across the NSS. Based on 170 animal years from collared females, 55% of individuals undertook seasonal migrations. Using between-class analysis of metrics, three distinct movement groupings were identified. Next, I modelled multi-scale migratory pathway selection in response to anthropogenic and environmental parameters. Generally, migratory pronghorn selected grasslands, intermediate slopes and south-facing aspects and avoided increased well and road densities. Pronghorn selected stopover sites with higher forage productivity values and lower well densities versus migratory pathways. I then used a scale-integrated mapping approach and found that these spatial predictions performed as well or better than single order scales to predict migration pathways. Finally, using a suite of novel approaches, I created seasonal pronghorn connectivity networks across the NSS. I concluded that multi-scale migration followed hierarchically nested theory where finer scale decisions are conditional on broader scales that can be assessed sequentially. I suggest that the pronghorn is a broad-scale focal species useful for conservation planning across the NSS.

**An Assessment of Current Statewide Avian Monitoring Programs in Montana

Will Janousek*, Avian Science Center, University of Montana, Missoula
Beth Hahn, Aldo Leopold Wilderness Research Institute, U.S. Forest Service Missoula, MT
Vicky Dreitz, Avian Science Center, University of Montana, Missoula

Birds are a highly diverse group consisting of species that use a wide-range of available resources. Therefore bird communities are thought to represent the natural complexity of ecosystems. In recent years, groups of birds and individual species have been recognized as indicators of environmental change. Even with all the potential benefits of conserving bird populations, considerable declines of avian populations in the US have been well documented. These losses highlight the need for continued large-scale monitoring programs. The North American Breeding Bird Survey (BBS) and the Integrated Monitoring in Bird Conservation Regions (IMBCR) are independent large-scale programs conducted within the US to monitor populations of birds. Each of these programs is uniquely designed to provide different types of information to resource managers within the state of Montana. We examined the current products available from BBS and IMBCR programs and the methodology employed. We also compared how each monitoring program assesses population change at the Montana state level across a variety of species to investigate potential program inconsistencies. If programs work equivalently we would expect abundance trend estimates to be in the same direction (positive or negative) and of similar magnitudes. Preliminary results suggest 94% (104/111) of species analyzed exhibited some difference in their abundance trend estimates between monitoring programs. Inconsistencies found within our species comparisons reflect inherent

differences in the programs. Our results reiterate the importance for users to carefully consider the unique design, intention, and sources of bias ascribed to each program before applying monitoring data to ecological questions.

**Recreational Aviation and Wildlife: the Physiological Stress Response in Deer and Associated User Perceptions

Devin W. Landry*, Wildlife Biology Program, University of Montana, Missoula
Elizabeth C. Metcalf, Wildlife Biology Program, University of Montana, Missoula
Creagh W. Breuner, Wildlife Biology Program, University of Montana, Missoula

Backcountry aviation is a popular form of recreation throughout the northern Rocky Mountains; however, it is unclear whether this seasonal disturbance has adverse effects on wildlife. Using stress physiology techniques provides a mechanistic understanding of the effects of disturbance on free-living populations. The analysis of fecal glucocorticoid metabolites (FGM) is an increasingly useful tool in conservation biology as it provides a non-invasive measurement of circulating stress hormones (e.g., cortisol) deposited into the feces. We quantified aircraft activity and human presence in concert with collecting white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) fecal samples from six backcountry airstrips and six non-airstrip recreational sites (n=12) located on public land throughout western Montana and north-central Idaho. By modeling deer FGM levels at these sites, we can evaluate the impacts of backcountry aviation on wildlife stress responses within the greater context of recreation on public lands. We also surveyed recreational pilots who frequent backcountry airstrips in the study area. The main objectives of this human dimensions analysis are to 1) measure attitudes of pilots toward seeing various wildlife species at backcountry airstrips and 2) evaluate scenarios under which pilots might alter their recreational behavior in order to mitigate potential wildlife impacts. This research represents the first attempt to model the endocrine profile of wildlife populations exposed to recreational, backcountry aviation while also providing data on current stakeholder attitudes regarding this topic. In doing so, we can gain an integrated understanding of the factors surrounding recreational aviation and wildlife bat backcountry airstrips.

Avian Relationships with Wildfire at Two Dry Forest Locations with Different Historical Fire Regimes

Quresh S. Latif*, Rocky Mountain Research Station, U.S. Forest Service, Bozeman, MT
Jamie S. Sanderlin, Rocky Mountain Research Station, U.S. Forest Service, Flagstaff, AZ
Victoria A. Saab, Rocky Mountain Research Station, U.S. Forest Service, Bozeman, MT
William M. Block, Rocky Mountain Research Station, U.S. Forest Service, Flagstaff, AZ
Jonathan G. Dudley, Rocky Mountain Research Station, U.S. Forest Service, Boise, ID

Wildfire is a key factor influencing bird communities in western North American forests. We need to understand species and community responses to wildfire and how responses vary regionally to effectively manage for biodiversity in dry conifer forests. We compared avian relationships with wildfire burn severity between two locations of Arizona and Idaho. We predicted different responses to wildfire corresponding with regional differences in historical fire regime. We conducted point-count surveys for 3 years following wildfire (Arizona: 1997–1999; Idaho: 2008–2010) and used multispecies hierarchical models to analyze relationships of bird occupancy with burn severity. Consistent with our prediction for mixed-severity fire regimes characterizing the Idaho location, we observed proportionately more positive species occupancy relationships and, consequently, a positive species richness relationship with burn

severity in Idaho. We also observed the opposite pattern in Arizona, which was congruent with our prediction for the low-severity fire regime characterizing that location. Cavity nesters and aerial insectivores occupied more severely burned sites following wildfire, corresponding with predicted increases in nesting substrate and foraging opportunities for these species. In contrast, canopy-nesting foliage gleaners and pine-seed consumers exhibited negative relationships with burn severity. Congruence with species life histories and with patterns reported in the literature suggests generality of observed patterns. We therefore suggest that optimal management strategies for maintaining avian diversity could differ regionally. Specifically, intensive fuels management may be ecologically less appropriate for promoting biodiversity in areas such as the Idaho location where mixed-severity wildfires and dense forest stands were historically more common.

Spion Kop Wind Farm: Montana Fish, Wildlife and Parks New Role in Wind Energy

Kimberly E. Linnell*, Montana Fish, Wildlife and Parks, Great Falls
Kristina M. Smucker, Montana Fish, Wildlife and Parks, Great Falls
Sam Milodragovich, NorthWestern Energy, Butte, MT

Montana Fish, Wildlife and Parks (FWP) has acquired a new role in working with NorthWestern Energy to plan and implement the post construction monitoring (PCM) at Spion Kop Wind Farm, located on the southern slopes of the Highwood Mountains near Geyser, Montana. The objectives of this project are not only to assess the bird and bat fatalities and impacts of habitat loss as a result of construction and operation, but to work together to make a standard for wind energy monitoring in Montana, implementing any further mitigation measures and research as determined by the outcome of the PCM, and eventually making all findings available to the public for reference. Using the U.S. Fish and Wildlife Service Land-Based Wind Energy Guidelines and Eagle Conservation Plan Guidance, FWP will estimate bird and bat fatalities through conducting formal fatality searches, assess the risk to eagles through standard eagle point counts, monitor all eagle nests within the project area, search for new nests through flight surveys, and monitor species of concern including bat activity, nesting of non-eagle raptors, and sharp-tailed (*Tympanuchus phasianellus*) grouse leks. Through early PCM work, an active Golden Eagle (*Aquila chrysaetos*) nest was discovered just .70 miles away from the nearest wind turbine. This, as well as the challenges realized through pilot fatality searches, has made FWP have to adapt the PCM plan accordingly. Where the project is currently as well as the future goals and objectives are addressed.

**Seasonal Resource Selection by Introduced Mountain Goats in the Southwest Greater Yellowstone Area

Blake Lowrey*, Ecology Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman
Sarah Dewey, Grand Teton National Park, Moose, WY
Gary Fralick, Wyoming Game and Fish Department, Thayne
Hollie Miyasaki, Idaho Department of Fish and Game, Idaho Falls

Mountain ungulates, although regarded as iconic and charismatic wildlife species, are the least studied and understood large mammals in the Greater Yellowstone Area (GYA). Mountain goats (*Oreamnos americanus*) are considered non-native in the GYA according to reviews of archeological, paleontological, and historical records, and have been steadily expanding their range since their initial introduction in the 1940s. Because of the general

propensity of mountain goats to inhabit high elevation, mountainous terrain, there is significant potential for range overlap with native bighorn sheep (*Ovis canadensis*) and the possibility that competition and disease transfer will be detrimental to sympatric bighorn populations. I will broadly discuss mountain goat seasonal resource selection modeled from 15 (11 females and 4 males) allopatric mountain goats representing the sole established population in the southwest GYA. These efforts produce the first spatial predictions of seasonal habitat use by mountain goats in the GYA using GPS data, and provide regional managers with important insights regarding the current and future distribution of mountain goats. Of particular interest are areas where mountain goats are in the early stages of colonization, such as Grand Teton National Park. Building seasonal resource selection models for mountain goats in the GYA is the first step needed to better understand their biological needs, ecological role, and potential to negatively impact native communities and species.

Evaluating Reproductive Success and Changes in Genetic Diversity of Grizzly Bears in Northwestern Montana

Nate Mikle *, US Geological Survey, Northern Rocky Mountain Science Center, West Glacier, MT
Tabitha Graves, US Geological Survey, Northern Rocky Mountain Science Center, West Glacier, MT
Ryan Kovach, US Geological Survey, Northern Rocky Mountain Science Center, West Glacier, MT
Kate Kendall, US Geological Survey, Northern Rocky Mountain Science Center, West Glacier, MT
Amy MacLeod, University of Alberta, Department of Renewable Resources, Edmonton

Current range expansions of large terrestrial carnivores are occurring following anthropogenically-induced range contraction. Contractions are often incomplete, leaving small remnant groups in refugia throughout the former range. We know little about underlying eco-evolutionary processes that influence how remnant groups are affected during range expansion. We used data from a spatially-explicit, long-term genetic sampling effort of grizzly bears (*Ursus arctos*) in the Northern Continental Divide Ecosystem (NCDE) to identify the processes underlying spatial patterns of genetic diversity. We conducted parentage analysis to evaluate how reproductive success and migration contribute to spatio-temporal patterns of genetic diversity in remnant groups of grizzly bears existing in the southwestern (SW), southeastern (SE), and east-central (EC) regions of the NCDE. Highly skewed reproductive success and local inbreeding caused distinct signatures in remnants that eroded rapidly (~1 generation) during population expansion and migration into the regions. Our results highlight that individual-level genetic and reproductive dynamics play critical roles during genetic assimilation, and show that patterns of genetic distinctiveness on the leading edge of an expansion may result from historical demographic patterns that are highly ephemeral.

Assessing Age Structure, Winter Ticks and Nutritional Condition as Potential Drivers of Fecundity in Montana Moose

Jesse R. Newby*, Montana Fish, Wildlife & Parks, Kalispell
Nicholas J. DeCesare, Montana Fish, Wildlife & Parks, Missoula
Justin A. Gude, Montana Fish, Wildlife & Parks, Helena

Fecundity in ungulates is an important component of population dynamics, and itself can be driven by differences in the age and nutritional condition of females. As one element of a larger research project focused on moose (*Alces alces*) population dynamics and ecology, we examined nutritional condition, pregnancy rates, and litter sizes for moose in three Montana

moose populations. During the winters of 2013–2015 we captured 100 female moose ≥ 1 year old and assessed pregnancy status using assays of both serum (pregnancy specific protein B [PSPB]) and feces (fecal progesterone). After calibrating the relationship between these two assays, we subsequently monitored pregnancy with feces alone for additional winters following capture. Coincident with captures, animals were aged using tooth extraction and cementum analysis, nutritional condition was assessed using ultrasonography of rump fat thickness, and winter tick loads were estimated by counting ticks along transects of the rump and shoulder. Additionally, the concentrations of nitrogen and neutral detergent fiber of winter pellets were measured during each winter as indices of dietary quality. Here, we assess the importance of environmental and demographic factors in limiting moose productivity in Montana by examining the interdependence of forage, parasites, nutritional condition, age structure, and ultimately fecundity for female moose. We then place these findings in context of fecundity rates observed for moose elsewhere within neighboring US Rocky Mountain populations and across North America.

PopR: Software for Wildlife Managers

J. Joshua Nowak*, Wildlife Biology Program, University of Montana, Missoula
Paul M. Lukacs, Wildlife Biology Program, University of Montana, Missoula
Justin Gude, Montana Fish, Wildlife & Parks, Helena
Mark Hurley, Idaho Fish & Game, Boise
Chelsea Krause, South Dakota Department of Game, Fish & Parks, Pierre
Andy Lindbloom, South Dakota Department of Game, Fish & Parks, Fort Pierre
Hugh Robinson, Panthera, New York, NY
Kevin Robling, South Dakota Department of Game, Fish & Parks, Rapid City

It is widely recognized that modern computer software makes wildlife management and research easier and allows increasingly complex tasks to become routine. Unfortunately, data storage and reporting rarely keep pace with the rapid expansion of data analysis software. Such disconnects in workflow can lead to missed opportunities where data are not used to their fullest extent and results are slow to emerge. Here we present a server-based software system, PopR (https://popr.cfc.umt.edu), which merges wildlife management agency databases with state-of-the-art statistical software for real-time wildlife data analysis, population modeling and reporting. The interface to PopR is a secure website allowing access from any location with internet access and from any platform (personal computer, smartphone, tablet, etc.). PopR connects to remote data sources through an application program interface (API). PopR implements Bayesian integrated population models (IPM) combining multiple data sources. The IPM's efficiently deal with limited data, overcome missing data and facilitate prediction with error. PopR also implements individual data source analyses such as survival, sightability and herd composition, among others. PopR modules are in development or in use in the states of Idaho, Montana and South Dakota where the software is used for a variety of species including deer, elk and mountain lions. Finally, add-on applications include tools for defining biological populations, checking data integrity and eliciting expert opinion. The PopR workflow management system promises to streamline data collection, automate routine analyses and generally save managers time while increasing inference from limited data.

**Participant Perceptions of Range Rider Programs Operating to Mitigate Wolf-Livestock Conflicts in the Western United States

Molly S. Parks *, Wildland Resources Department, Utah State University, Logan
Terry A. Messmer, Wildland Resources Department, Utah State University, Logan

As gray wolf (*Canis lupus*) populations have expanded in the western United States, wolf depredations on domestic livestock have increased. Concomitantly, wildlife managers are seeking management tools that could mitigate wolf-livestock conflicts and enhance stakeholder support for conservation efforts. Range Rider Programs (RRPs) have emerged as a non-lethal management strategy that advocates the use of increased human surveillance of livestock herds in area occupied by wolves to reduce wolf-livestock conflicts. However, little information is available about the scope of contemporary NRM RRPs or participant perceptions about the potential for the programs to mitigate these conflicts. We conducted semi-structured phone and personal interviews with 51 participants from 17 Range Rider Programs (RRPs) in Montana, Oregon, and Washington to develop a typology of NRM RRPs and assess participant perceptions of current programs. Although the RRPs we studied varied in context, program focus and scale, they shared similar organizational components that included: a sponsor, collaboration among several organizations, a funding mechanism, a structure that included a supervisor, the landowner(s) and the range rider(s), and a mechanism for stakeholder feedback. We identified three unique RRP versions based on the primary focus of the programs: 1) livestock monitoring, 2) wolf surveillance and 3) livestock herding. While participants identified a number of benefits (e.g. increased information on wolf activity, extra herd supervision, rapid carcass identification), they also identified challenges which affected program sustainability. Challenges pertaining to trust and open communication were inherent in several programs, however the lack of stable funding was viewed as a major threat to program sustainability. The final challenge to RRPs sustainability was the largely unproven success of this strategy.

**Variation in Birth Mass and Mass Gain During Lactation for a Long-Lived Mammal: A Case Study Using the Weddell Seal

J. Terrill Paterson*, Ecology Department, Montana State University, Bozeman
Jay J. Rotella, Ecology Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman

Reproduction in mammals is costly, with implications for trade-offs between current reproduction and survival. Life history theory suggests the amount of energy allocated to reproduction should change as a function of increasing maternal age, and empirical work supports both within-individual decreases (consistent with senescence) and increases (consistent with constraint and restraint). The Weddell seal (*Leptonychotes weddellii*) is an ideal organism with which to study patterns of maternal energy allocation due to the life history. Here, we used a long-term mark-recapture database of individually marked mothers and pups in Erebus Bay, Antarctica, to develop a stratified sample of masses from pups and known-age females across maternal ages in 11 different years. Hierarchical modeling of potential sources of variation in: 1) pup masses at parturition, 2) pup mass gains from parturition to mid-lactation (~20 days), and 3) pup mass gains from mid-lactation to late-lactation (~20-days to ~35-days) was used to 1) evaluate the relative support for increases/decreases in reproductive allocation as a function of maternal age, 2) assess how patterns of

reproductive allocation may reflect pre-parturition resource acquisition and/or post-parturition resource allocation, and 3) estimate the magnitude of individual heterogeneity in maternal effects after accounting for maternal and offspring characteristics. Our results provide strong evidence that reproductive investment at parturition and pup mass gains from parturition through late-lactation vary with maternal age and breeding history and result in important differences in late-lactation pup masses. Such variation may have consequences for the early-life success of offspring, and thus implications at the population level.

American Black Bear Population Fragmentation Determined Through Pedigrees in the Trans-Border Canada-United States Region

Michael F. Proctor, Birchdale Ecological Ltd., Kaslo, British Columbia

Wayne F. Kasworm*, US Fish and Wildlife Service, Libby, MT

Chris Servheen, US Fish and Wildlife Service, College of Forestry and Conservation, University of Montana, Missoula

Justin E. Teisberg, US Fish and Wildlife Service, Libby, MT

Thomas G. Radandt, US Fish and Wildlife Service, Libby, MT

David Paetkau, Wildlife Genetics International, Nelson, British Columbia

Katherine C. Kendall, United States Geological Survey–Northern Rocky Mountain Science Center, Glacier Field Station, West Glacier, MT

Richard D. Mace, Montana Fish, Wildlife, and Parks, Kalispell

Mark S. Boyce, Department of Biological Sciences, University of Alberta, Edmonton

Fragmentation of species with large numbers of individuals in adjacent areas can be challenging to detect using genetic tools as there often is no differentiation because genetic drift occurs very slowly. We used a genetic-based pedigree analysis to detect fragmentation in the American black bear (*Ursus americanus*) across 2 highways with large adjacent populations. We used 20 locus microsatellite genotypes to detect parent-offspring and full sibling pairs within a sample of 388 black bears. We used the spatial patterns of capture locations of these first order relatives relative to US Highway 2 in northwest Montana and Highway 3 in southeast British Columbia to estimate the number of close relatives sampled across the highways (migrants/km of highway length) as an index of fragmentation. We compared these values to an expected migrant/km rate derived from the mean values of simulated fractures in the Highway 2 and Highway 3 region. We found evidence that these highway corridors were fragmenting black bear populations, but not completely. The observed migrant/km rate for Highway 2 was 0.05, while the expected rate was 0.21 migrants/km. Highway 3 had an observed migrant/km rate of 0.09 compared to the expected rate of 0.26. None of the 16 bears carrying GPS radio collars for 1 year crossed Highway 2, yet 6 of 18 crossed Highway 3. Pedigree and telemetry results were more closely aligned in the Highway 2 system evidencing more intense fragmentation than we found along Highway 3. Our results demonstrate that pedigree analysis may be a useful tool for investigating population fragmentation in situations where genetic signals of differentiation are too weak to determine migration rates using individual-based methods, such as population assignment.

Linking Landscape-Scale Differences in Forage to Ungulate Nutritional Ecology

Kelly M. Proffitt*, Montana Fish Wildlife and Parks, Bozeman
Mark Hebblewhite, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula
Wibke Peters, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula
Nicole Hupp, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula

Understanding how habitat and nutritional condition affect ungulate populations is necessary for informing management, particularly in areas experiencing carnivore recovery and declining ungulate population trends. Variations in forage species availability, plant phenological stage, and the abundance of forage make it challenging to understand landscape-level effects of nutrition on ungulates. We developed an integrated spatial modeling approach to estimate landscape-level elk (*Cervus elaphus*) forage quality in two adjacent study areas that differed in coarse measures of habitat quality and related the consequences of differences in forage quality to elk body condition and pregnancy rates. We found no support for differences in dry matter digestibility between plant samples or in phenological stage based on ground sampling plots in the two study areas. Forage quality, measured as digestible forage biomass, varied among land cover types and between study areas. We found that altered plant composition following fires was the biggest driver of forage quality differences, suggesting that maintaining a mosaic of fire history and distribution will likely benefit ungulate populations. Study area, lactation status and year affected fall body fat of adult female elk. Elk in the study area exposed to lower quality summer range forage had lower nutritional condition entering winter. These differences in nutritional condition resulted in differences in pregnancy rate, with average pregnancy rates of 89% for elk exposed to higher quality forage and 72% for elk exposed to lower quality forage. Summer range forage quality has the potential to limit elk pregnancy rate and calf production, and these nutritional limitations may predispose elk to be more sensitive to the effects of harvest or predation. Wildlife managers should identify ungulate populations that are nutritionally limited and recognize that these populations may be more impacted by recovering carnivores or harvest than populations inhabiting more productive summer habitats.

Evaluating Elk Summer Resource Selection and Applications to Summer Range Habitat Management

Dustin H. Ranglack*, Department of Ecology, Montana State University, Bozeman
Kelly M. Proffitt, Montana Fish, Wildlife, and Parks, Bozeman
Justin Gude, Montana Fish, Wildlife, and Parks, Helena
Jodie Canfield, Custer Gallatin National Forest, USDA Forest Service, Bozeman
Jay Rotella, Department of Ecology, Montana State University, Bozeman
Robert A. Garrott, Department of Ecology, Montana State University, Bozeman

In much of the west, National Forest lands are managed in part to provide and protect elk (*Cervus elaphus*) habitat needs, and summer elk habitat is managed with consideration to motorized routes. We evaluated the relative importance of nutritional resources, access routes and other landscape attributes on elk summer resource selection at multiple spatial scales. Resource selection models for 9 different western Montana elk populations, as well are regional models using data from all 9 herds, were compared to determine the applicability of resource selection models for informing habitat management recommendations. We found that

in all populations nutritional resources, best represented using NDVI metrics, were the most important factors associated with elk summer resource selection. Access route disturbances, best represented by the density of all routes (i.e., routes open and closed to motorized use), affected resource selection in all populations, however, the influence of access routes was relatively small as compared to nutritional resources. Regional models of resource selection predicted resource selection across populations better than population-specific models, thus we recommend these types of models be used to inform regional habitat management. Our results suggest that managers should expand the current management paradigm for elk summer habitat to also consider nutritional resources as an important component of elk summer habitat. Time-integrated NDVI, an easily accessible and free data source, may be useful as an assessment tool to identify areas of optimal elk nutrition.

**Grizzly Bear Scavenging of Carrion on the Northern Yellowstone Winter Range (1997-2012)

Brooke S. Regan*, Department of Animal and Range Sciences, Montana State University, Bozeman
Frank T. van Manen, Interagency Grizzly Bear Study Team, U.S. Geological Survey, Bozeman, MT
Lance McNew, Department of Animal and Range Sciences, Montana State University, Bozeman
Daniel Tyers, Interagency Grizzly Bear Study Team, USDA Forest Service, Bozeman, MT
Kerry Gunther, Yellowstone Center for Resources, Yellowstone National Park, WY
Bok Sowell, Department of Animal and Range Sciences, Montana State University, Bozeman
Douglas W. Smith, Yellowstone Center for Resources, Yellowstone National Park, WY

The Northern Yellowstone Winter Range (NYWR) in northwestern Wyoming and southwestern Montana is an important winter migratory destination for ungulates. The NYWR is within the Greater Yellowstone Ecosystem (GYE), a landscape characterized by a complex ecological system of predators, scavengers, and ungulates. Grizzly bears (*Ursus arctos*) are dominant members of the scavenging community throughout the spring. However, little is known about factors associated with grizzly bear use of carcasses. Of particular interest to managers is how habitat and anthropogenic factors are associated with carcass use. Such information, for example, may be useful to manage spring recreation in important bear foraging areas to reduce conflict and support conservation efforts. We used logistic regression to analyze spring survey data from 23 transects located in Yellowstone National Park and the Gallatin National Forest during 1997–2012, to identify factors associated with grizzly bear scavenging of winter- or predator-killed ungulates. Multi-model inference was used to evaluate relative support for a set of *a priori* candidate models containing environmental and temporal correlates. Our preliminary findings showed support for models with distance to forest edge, road density, and elevation. Results indicated negative relationships between these factors and probability of carcass use. Our results suggest that spatial heterogeneity in landscape-level habitat characteristics and human activity affect grizzly bear use of a valuable spring food source.

Citizen Scientist Monitoring of Osprey Distribution and Reproductive Success Along the Yellowstone River, MT

Marco Restani*, Montana Audubon, Helena
Deb Regele, Yellowstone Valley Audubon Society, Billings, MT
Monty Sullins, Yellowstone Valley Audubon Society, Billings, MT
George Mowat, Yellowstone Valley Audubon Society, Billings, MT
Robert Lubbers, Yellowstone Valley Audubon Society, Billings, MT

The Yellowstone Valley Audubon Society monitors ospreys (*Pandion haliaetus*) nesting along the Yellowstone River 1) to increase science literacy by engaging volunteers and undergraduate interns in conservation, 2) to reduce conflicts between utility companies and ospreys nesting on power poles, and 3) to rescue nestlings entangled in baling twine used in nest construction. Trained volunteers surveyed the study area and determined reproductive success for occupied nests from April through August 2012-2015. All nests were located on anthropogenic substrates: platforms on poles, bridge spans, power poles, and cell towers. Mean (SE) number of young fledged per occupied nest was above that needed to sustain the local population: 1.87 (0.22) in 2012 (n = 30 nests), 1.35 (0.18) in 2013 (n = 48 nests), 1.51 (0.16) in 2014 (n = 55 nests), and 1.48 (0.17) in 2015 (n = 62 nests). Although some nest sites consistently produced more fledglings than others, reproductive success was unrelated to distance to nearest neighbor, density of breeding pairs within 5 km, and location along the river. From 2012-2015, 11 nestlings and one adult became entangled in baling twine: three died, one was euthanized, and eight nestlings fledged normally after being freed. A disease of unknown etiology appeared to affect nearly 50% of nestlings in 2015. Carcasses tested by the National Wildlife Health Center were negative for Avian Influenza, West Nile Virus, and Newcastle Disease. The discovery of new nests annually, robust reproductive success, and relatively low density suggested the population was in the growth phase.

**Trapping Methods of the Feral Pigeon in the Central Business District of Butte, Montana

Cody Richardson*, Montana Tech, Butte
Dr. Stella Capoccia, Montana Tech, Butte
Dr. Julie Hart, Montana Tech, Butte

The purpose of this study is to illustrate innovative trapping methods for the successful capture of feral pigeons (*Columba livia*). Our results highlight unique characteristics of the pigeon's behavior that, when harnessed, increase success in trapping frequency and bird numbers and underscore the importance of understanding a species behavior when conducting biological research. Our results came about when conducting a population study of pigeons throughout the central business district (CBD) of Uptown Butte, MT. Through a succession of trial-and-error trapping efforts, we identified two aspects of trapping our target species: 1) minimal information exists on effective trapping protocol for pigeons, and 2) effective trapping protocol was closely tied to specific adjustments that prove effective in a number of different pigeon colonies. While pigeons differ from truly wild animals, insofar as they are a Eurasian species and feral, free-roaming colonies of pigeons offer excellent ecological models for studies that include population models, behavioral studies, handling protocol, and, of course, trapping. Our methods address conventional trapping and tagging techniques as well as innovative procedures and traditional urban point-count surveys. These innovative procedures would help with re-sighting tagged birds within the survey routes. All these methods will collectively provide insight into dispersal, recruitment, foraging and abundance of pigeons.

**Habitat Selection, Movements and Survival of Dispersing Juvenile Beavers in Southwestern Montana (Oral & Poster)

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

The natural activities of beavers (*Castor canadensis*) effectively create or expand, and maintain, healthy riparian and wetland areas. Therefore, interest has increased among land and wildlife managers in the reintroduction of beavers into degraded riparian habitats as a proactive management option for natural restoration of these areas. However, there is a need for information regarding habitat selection by beavers in novel habitats to increase the likelihood that reintroduced beavers will colonize the area targeted for restoration. We are using cable snares to capture and radio tag dispersal age beavers in headwater streams of the Madison and Gallatin River drainages. We will relocate tagged beavers via handheld telemetry to obtain movement data from the moment the beavers leave their natal colony in the spring until they settle in a new location in the late summer and fall. Habitat characteristics representing vegetation, hydrology and geomorphology will be assessed at settlement locations as well as locations encountered but not settled to make inference on habitat conditions most important to dispersing beavers in selecting settlement sites. Eighteen beavers were radio tagged in the fall of 2015 representing 6 different streams in the study area. The 18 tagged beavers will be tracked through the spring and summer of 2016 and habitat conditions will be assessed based on their movements before another season of beaver trapping in the fall of 2016. Our analysis of habitat selection by juvenile beavers will guide future beaver restoration projects in this region by identifying release sites with the highest probability of success.

Forty-Five Years of Grizzly Bear Mortality in the Northern Continental Divide Ecosystem

Lori Roberts*, Montana Fish, Wildlife and Parks, Kalispell
Cecily Costello, Montana Fish, Wildlife and Parks, Kalispell

Within the last 10 years, the grizzly bear (*Ursus arctos*) population in the Northern Continental Divide Ecosystem (NCDE) has increased in size and doubled its range. Understanding the changes in mortalities is important to guide management of the population. Montana Department of Fish, Wildlife and Parks has maintained a record of documented grizzly bear mortalities since 1971. During this time there were a total of 650 human-caused, independent-aged (≥2 years old) bear mortalities recorded. We reviewed the last 45 years of human-caused grizzly bear mortalities in the NCDE, to determine any changes in mortality demographics, mortality causes, and spatial distribution. During 1975–1992, a quota of 25 human-caused mortalities was in effect and a slight temporal decline in total mortality was observed. Since 1992, the trend in total mortalities has been increasing at approximately 3%/year. Agency removals comprised 24% of human-caused mortalities. Previously, removals were largely associated with anthropogenic foods, but livestock depredations have been the primary cause for removals during the last two decades. Among public-caused mortalities (76%), legal hunting (during 1971–1991) and poaching/malicious kill have been the most dominant causes of death. Defense of life kills and automobile and train collision deaths have increased over time. During the last decade, there was an increase in the number of females with young present that were killed by the public. Whereas most mortalities occurred inside the Recovery Zone during the 1970s and 1980s, >50% now occur outside of it. Wildlife managers can use this information for developing strategies for managing grizzly bear mortality and improving bear-human coexistence.

**Redistribution, Human Shields and Loss of Migratory Behavior in the Crown of the Continent

Wesley Sarmento*, Wildlife Biology Program, The University of Montana, Missoula
Mark Biel, Natural Resources, Glacier National Park, West Glacier, MT
Joel Berger, Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, and Wildlife Conservation Society, Bronx, New York

Redistribution of wildlife resulting from human alteration of environments is of growing management concern in North America. Habituation, which can coincide with redistribution, seems to be particularity prevalent in national park systems because millions of visitors interact with wildlife. For example, Glacier National Park in northwestern Montana, USA, receives approximately 2.2 million visitors over the months of June, July, and August each year—with the majority of their activity concentrated along the Going-to-Sun Road. The Going-to-Sun Road corridor is well-known for its habituated mountain goats (*Oreamnos americanus*). Habituation, however, was identified as a priority management concern in Glacier National Park. Successful management actions require a clear understanding of the causes and consequences of complex ecological issues such as habituation. Through experimental and observation effort this project has identified human-created predation refugia, or human shields, where mountain goats are escaping predation through interaction with people. Reductions in predation risk have resulted in mountain goat redistribution and changes in behavior. We found mountain goats using sites with human shields were less vigilant and were found in smaller groups. Furthermore, goats in areas with human-mediated predation refuge had reduced use cliff security terrain. Additionally, mountain goats that exploited people as shields from predators showed a weakened response to an experimentally presented predator model. Reductions in predator risk appear to be the primary driver of mountain goat redistribution and the use of humans as buffers from predation has led to close contact between people and wildlife, resulting in compromised safety and altered ecological interactions.

**Fine Scale Nest Site Selection of Greater Sage-Grouse In The Centennial Valley, Montana

Sean R. Schroff *, Animal & Range Sciences, Montana State University, Bozeman
Kyle A. Cutting, Red Rock Lakes NWR, US Fish & Wildlife Service Lima, MT
Bok F. Sowell, Animal & Range Sciences, Montana State University, Bozeman
Craig A. Carr, Animal & Range Sciences, Montana State University, Bozeman
Michael R. Frisina, Animal & Range Sciences, Montana State University, Bozeman

The purpose of this study was to determine fine scale nest site selection of greater sage-grouse (*Centrocercus urophasianus*) in the Centennial Valley, MT. A total of ninety nests were found during 2014-2015 using radio-collared sage-grouse. Vegetation surveys were conducted at nests and random sites that measured the nest shrub and the cover available within 3m of the nest. Length of the branch over the nest (Lgth.LB), average axis width of the nest shrub (AvgAxis), lateral cover of the nest shrub (LCShrub), aerial cover of the nest shrub (ACShrub), and height of the lower branch over the nest (Ht.LB) were the habitat variables that received the most support. All habitat variables that were included in the top model were nest shrub morphological characteristics and cover provided by the nest shrub. Therefore, there is strong support that sage-grouse in the Centennial Valley are selecting nest sites based on the morphology of the nest shrub and the cover provided by that nest shrub. None of the habitat variables associated with herbaceous cover received much support for inclusion in our models. On average, residual cover (i.e. grass from previous year) provided concealment

for only 4% of the nest bowl. The relative probability of a shrub being selected for a nest site is maximized when Lgth.LB >75cm long, AvgAxis >130cm wide, LCShrub >80%, and ACShrub > 70%. Managers should focus on conserving mountain big sagebrush (*Artemisia tridentata* ssp. vaseyana) and three-tip sagebrush (*Artemisia tripartita*) habitats because they were more likely to meet those shrub characteristics.

Bat Activity Patterns and Roost Selection in Managed Forests

Nathan A. Schwab *, ABR, Inc., Missoula, MT
Lorin L. Hicks, Plum Creek Timber Company, Columbia Falls, MT

The recent introduction and subsequent westward spread of white-nose syndrome (WNS) has decimated hibernating bat populations in eastern North America and created an urgent need for scientists to understand basic information about bat ecology, especially during the winter season. White-nose syndrome has killed between 5 and 7 million bats and continues to spread westward from the eastern U.S. and southern Canada, primarily affecting bats during hibernation. Acoustic monitoring has been suggested as a potential surveillance tool for detecting WNS; however, baseline information must first be collected to test this technique. Recent interests in habitat for resident bats has focused on managed forests, particularly in western Montana, where caves used as communal winter hibernacula are not abundant. We initiated a pilot project in June 2014 deploying 2 remote acoustic monitoring stations on Plum Creek property in Flathead County and adding an additional 2 stations in forests owned by Stoltze Land and Lumber and Stimson Lumber Company in May 2015 to collect baseline acoustic information. We also conducted radio telemetry to determine characteristics of roosts used by bats during the fall season in 2014 and 2015. Thus far we have acoustically detected 11 of Montana's 15 bat species, observed extremely high activity levels during the summer, and detected bat activity during every month of the year. We radio-tagged 14 bats of 4 different species; California myotis (*Myotis californicus*), Western small-footed myotis (*Myotis ciliolabrum*), Silver-haired bat (*Lasionycteris noctivagans*), Little brown bat (*Myotis lucifugus*) and tracked them in late October and early November. Identifying the characteristics of roost sites used during the pre-hibernation period, and the annual activity patterns determined from acoustic monitoring, begin to form the foundation for understanding basic aspects of bat ecology during the season when Montana bats will be most susceptible to WNS.

**Application of Structured Decision Making to Wildlife Management in Montana

Sarah N. Sells*, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Michael S. Mitchell, U.S. Geological Survey, Montana Cooperative Wildlife Research Unit, University of Montana, Missoula
Justin A. Gude, Montana Fish, Wildlife and Parks, Helena
Neil J. Anderson, Montana Fish, Wildlife and Parks, Bozeman

Good decision-making is essential to conserving wildlife populations. Whereas there may be multiple ways to address a problem, perfect solutions rarely exist. Managers are therefore tasked with identifying optimal decisions that will best achieve desired outcomes. Structured decision making (SDM) is a method of decision analysis used to identify the most effective, efficient, and realistic optimal decisions while accounting for values and priorities of the decision maker. The stepwise process includes identifying the management problem, defining objectives for solving the problem, developing alternative approaches to achieve

the objectives, and formally evaluating which alternative is most likely to accomplish the objectives. The SDM process can be more effective than informal decision-making because it provides a transparent way to quantitatively evaluate decisions for addressing multiple management objectives while incorporating science, uncertainty, and risk tolerance. We illustrate the application of this process to management needs, including an SDM-based decision tool developed to identify optimal decisions for proactively managing risk of pneumonia epizootics in bighorn sheep (*Ovis canadensis*). Pneumonia epizootics are a major challenge for managers, including in terms of knowing how or when to manage risk. The decision tool facilitates analysis of alternative decisions for how to manage herds based on predictions from a risk model, herd-specific objectives, and predicted costs and benefits of each alternative. Managers can be confident resulting decisions are most effective, efficient, and realistic because they explicitly account for important considerations managers implicitly weigh when making decisions, including competing management objectives, uncertainty in potential outcomes and risk tolerance.

Golden Eagle Migration Corridors along The Rocky Mountain Front and Intermountain Flyways

Adam Shreading*, Raptor View Research Institute, Missoula, Montana
Bryan Bedrosian, Teton Raptor Center, Wilson, Wyoming
Robert Domench, Raptor Raptor View Research Institute, Missoula, Montana
Mathew Hayes, Lone Pine Analytics, Laramie, Wyoming
Vince Slabe, Raptor View Research Institute, Missoula, Montana

Golden Eagles (*Aquila chrysaetos*) have been receiving increased attention in the western United States due to an increase in anthropogenic population threats, including wind and other industrial energy developments. Conservation of migratory Golden Eagles hinges on knowledge of threats within breeding ranges, migratory corridors, and over-wintering areas. Often, understanding threats along migration corridors can be difficult due to the short temporal use of migration paths and because pathways can often be dispersed across the landscape. We used satellite tracking data from three Golden Eagle studies across Montana to estimate key migration routes and bottlenecks for migratory Golden Eagles wintering or passing through Montana, with an emphasis on the Rocky Mountain Front. We gathered data from 35 individuals, including from 21 adult and 14 sub-adult Golden Eagles. We created individual dynamic Brownian Bridge Movement Models (dBBMM) for each migration event to estimate migratory pathways of individuals. We also created a population level migratory pathway estimate to determine key migration corridors and bottlenecks by summing the individual dBBMMs after accounting for age and study location. These models can be used for future risk assessments for developments and conservation measures for Golden Eagle migration routes.

Montana's Greater Sage Grouse Conservation Strategy: All Hands Across All Lands

Carolyn A. Sime*, Montana Department of Natural Resources and Conservation, Helena

The greater sage grouse (*Centrocercus urophasianus*) was once a candidate for listing under the federal Endangered Species Act across its range. Unprecedented efforts by states, federal agencies, private organizations, and private landowners led to adoption of conservation strategies to address threats caused by habitat fragmentation, development, and loss of sagebrush. Montana's Conservation Strategy is based on the collaborative work of a governor-appointed advisory council, the Montana Sage Grouse Stewardship Act passed

during the 2015 Legislative Session, and Executive Orders 12-2015 and 21-2015. Montana's Strategy has three parts. First, Executive Orders 12-2015 and 21-2015 establish regulatory mechanisms to guide development in designated habitats. The Orders require consultation to assess potential impacts caused by activities requiring a state permit, involving state grant funds or technical assistance, or resulting from the state's own work. Federal agencies will align project review with the Orders. Specific parameters and disturbance thresholds apply, particularly for human activities near leks. Second, the Stewardship Grant Fund serves to maintain, enhance, restore, expand or benefit sage grouse. The Fund facilitates free-market mechanisms for voluntary, conservation on private lands by funding projects that produce credits. Credits can then be purchased by developers in a habitat exchange. Third, the habitat exchange establishes a compensatory mitigation framework to address impacts which cannot avoided, minimized, or restored and replacement is required. Montana's goal is to maintain viable sage grouse populations and conserve habitat and maintain Montana's flexibility to manage its own lands, wildlife, and economy. Success requires collaboration across all landownerships to address all threats.

**Life History Traits as Mediators of Solitary Bee Responses To Climate-Warming

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

Climate-warming is uncoupling plant-pollinator interactions by causing species-specific shifts in seasonal flowering periods and pollinator activity times (i.e. phenologies). The mechanisms mediating pollinator responses to warming are poorly understood, preventing conservation professionals from identifying the most at-risk species and limiting our understanding of the potential effects of climate warming on plant-pollinator communities. The goal of this study was to experimentally investigate whether solitary bee (*Hymenoptera* spp.) overwintering life stages influence phenological responses to climate-warming. Climate-controlled growth chambers where used to manipulate the temperature bees experienced while developing and overwintering. Results suggest that different physiological constraints associated with overwintering in the prepupal life stage compared to the adult life stage may influence how solitary bees respond to climate-warming in predictable ways. Bees that overwinter as adults may be more prone to phenological mismatches in the spring, while bees that overwinter as prepupae may be more prone to phenological mismatches in mid summer. In addition, the phenologies of bees that overwinter as adults may be converging with the phenologies of bees that overwinter as prepupae, causing reduced pollinator abundance during late summer and altering competition among bees for nectar and pollen during early summer. This work demonstrates that life history traits of bees may mediate their responses to climate-warming. These findings contribute to a better understanding of the effects of climate warming on pollinator species, with implications for preserving pollination services in Montana, as well as informing future studies investigating the effects of climate warming on plants and pollinators.

Current Status of Efforts to Restore Northern Leopard Frogs to the Flathead Reservation in Northwest Montana

Art Soukkala*, Confederated Salish and Kootenai Tribes, Pablo, MT

One long term goal of the Confederated Salish and Kootenai Tribes Wildlife Management Program is to restore populations of native wildlife species on the Flathead Indian Reservation. In 2003 we embarked on a project to restore populations of northern leopard

frogs (*Lithobates pipiens*), a species not documented on the Reservation since 1980. Over the next 4 years, 26 egg masses were translocated from populations in eastern Montana to a release site on the Reservation. Although tadpoles developed and metamorphosed successfully, we could not document significant overwintering survival. In 2006 a second release site was chosen in a newly restored wetland along the Little Bitterroot River. A total of 128 egg masses have been translocated to this and surrounding wetlands since 2006. Overwintering survival was suspected in 2007 and confirmed in 2008. Adult leopard frogs were first heard calling at this release site in 2010. A significant milestone in the project was achieved when egg masses were documented in 2013. This represented the first documented breeding of northern leopard frogs on the Flathead Reservation in over 30 years. Since 2013, the number of egg masses documented at our release wetland has increased giving us guarded optimism. Future plans include continuing to translocate egg masses into the Little Bitterroot River release wetland and additional nearby wetlands in an attempt to diversify breeding sites within the localized population. Pilot releases will be made in other areas in an attempt to reach our ultimate goal of 5 breeding populations on the Flathead Indian Reservation.

Common Poorwill Habitat Use and Breeding Ecology in Western Montana

Katharine Stone*, MPG Ranch, Florence, MT

We know relatively little about Common Poorwill (*Phalaenoptilus nuttallii*) natural history or habitat needs in Montana. Most published range maps do not show them occurring west of the Continental Divide in Montana. However, surveys targeting other birds led to numerous incidental detections of Common Poorwills on the MPG Ranch, a private conservation property in the Sapphire Mountains just south of Missoula. In 2015 we started a pilot project on the MPG Ranch to more closely examine poorwill distribution, habitat use, and breeding ecology. We also used Citizen Scientists from Bitterroot Audubon to survey for poorwills in other parts of the valley. On the MPG Ranch, we found poorwills widely distributed in habitats with a mixture of a shrubby overstory, steep terrain, and talus slopes. In some cases poorwills roosted and/or nested in areas with tree cover. We captured 11 individuals and tested radio telemetry techniques to approximate range size, roost use, and site fidelity. We monitored activity at six nests and deployed motion-sensing cameras when possible to observe nesting behavior. We also used acoustic monitors and roadside observations to document arrival and departure dates. We plan to expand this project in 2016.

**Influence of Infanticide Risk on Brown Bear Den-Site Selection

Lindsey A. Stutzman*, Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, Mississippi

Jerrold L. Belant, Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, Mississippi

David D. Gustine, National Park Service, Grand Teton National Park, Moose, WY

Timothy L. Hiller, Department of Wildlife, Fisheries, and Aquaculture, Mississippi State University, Mississippi

Buck A. Mangipane, National Park Service, Lake Clark National Park & Preserve, Port Alsworth, AK

Grant V. Hildebrand, U.S. Geological Survey, Alaska Science Center, Anchorage

The risk of infanticide in brown bears (*Ursus arctos*) may influence den-site selection and chronology for female brown bears with dependent young. Strategies to reduce risk of infanticide include females avoiding larger, more dominant adult males through spatial

or temporal segregation. We assessed whether variation in den location, den habitat, and den entrance and emergence dates of male and female bears supported sexual segregation in Lake Clark National Park and Preserve, Alaska. Den-sites (n = 56) were located using GPS telemetry data from bears in 2014 (n = 21) and 2015 (n = 35). We used mixed model analysis of variance to compare slope, elevation, and aspect of den sites for adult male and adult female bears with and without dependent young. We also used these variables to model probable denning habitat using maximum entropy modeling. We examined timing of female den entry and emergence in relation to males using generalized linear mixed models. Our preliminary results using 2014 data suggest that females with dependent may den at higher elevations (944 ± 140 m, $\bar{x}$ ± SD) than solitary females (866 ± 189 m) but at lower elevations (984 ± 118 m) than males. They also may use less steep slopes (25 ± 11.8°) than solitary females (29 ± 9.9°) or males (34 ± 4.9°). Additionally, females with dependent young (Julian day: 289 ± 8 days) denned 2 days later than solitary females (287 ± 6 days) and 20 days earlier than males (309 ± 21 days). Females with dependent young (122 ± 17 days) also emerged from dens 6 days earlier than solitary females (128 ± 9 days) and 10 days earlier than males (132 ± 10 days). Differences in den entrance and emergence dates suggest support our hypothesis that females with dependent young temporally segregate from male bears.

Diet Composition and Body Condition of Northern Continental Divide Grizzly Bears, Montana

Justin E. Teisberg *, US Fish and Wildlife Service, Libby, MT
Michael J. Madel, Montana Fish, Wildlife and Parks, Choteau
Richard D. Mace, Montana Fish, Wildlife and Parks, Kalispell
Lori Roberts, Montana Fish, Wildlife and Parks, Kalispell
Joy Erlenbach, Schools of the Environment and Biological Sciences, Washington State University, Pullman
Christopher W. Servheen, U.S. Fish and Wildlife Service, University of Montana, Missoula
Charles T. Robbins, Schools of the Environment and Biological Sciences, Washington State University, Pullman

From 2009–2013, we documented apparent population health by investigating food use and physiological condition of grizzly bears (*Ursus arctos)* in the Northern Continental Divide Ecosystem (NCDE), Montana. We used stable isotope analysis upon hair and blood tissue to obtain information on percent terrestrial meat and plant matter in the diets of NCDE bears. We also assessed body fat content of grizzly bears via bioelectrical impedance analysis. Adult females used less meat compared to subadults and adult males ($P < 0.0001$). Bears within regions on the southwestern, southern, and eastern periphery of the ecosystem consumed a significantly higher proportion of meat than those in the interior or northwestern periphery ($P < 0.0001$). Diets of bears in the Whitefish Mountains and North and South Fork of the Flathead River were, on average, composed of 70% less meat than those on the East Front. Adult males had significantly higher den entrance body fat contents than adult females and subadults ($P < 0.0001$). Average body fat of adult females varied significantly between those in areas of high consumption of meat and those otherwise. However, we find adult females across all regions enter dens at mean fat levels above those thought to be critical for cub production (i.e., > 20%). We conclude that, within each region, the quantity and quality of foods appear adequate to meet the needs of reproductively-active adult females. As truly opportunistic omnivores, grizzly bears in each region of the NCDE exploit diverse combinations of food items to arrive at productive body conditions.

Effects of Hunter Access on Hunting Season Elk Distributions in the Missouri River Breaks

Scott Thompson*, Montana Fish, Wildlife and Parks, Glasgow
Drew Henry, Montana Fish, Wildlife and Parks, Glasgow
Kelly M. Proffitt, Montana Fish, Wildlife and Parks, Bozeman
Justin Gude, Montana Fish, Wildlife and Parks, Helena

Increasing harvest of adult female elk (*Cervus elaphus nelsoni*) is the primary management tool for curtailing elk population growth and reducing elk populations. However, this tool is not effective when elk are located on private properties that restrict hunter access to elk during the hunting season. The purpose of this project was to evaluate the effects of hunter access and other landscape factors on elk resource selection during the archery and rifle hunting seasons in the Missouri River Breaks area. We sampled 46 adult female elk for 2-years in 2 adjacent populations: the Missouri River Breaks (MRB) population and the Larb Hills population. The MRB archery and rifle season elk population ranges were 97% accessible to hunters. Several large properties in the center of the Larb Hills range restricted or did not allow hunter access, and the archery and rifle season elk population ranges were 79% accessible to hunters. To quantify the effects of hunter access and other factors on elk selection of home ranges and elk selection of locations within their home range, we conducted a resource selection modeling exercise. Second-order population-level selection coefficients showed that elk in both MRB and Larb Hills selected home ranges in areas with no hunter access, and hunter access was the strongest predictor of second-order selection. Similarly, third-order population-level selection coefficients showed elk in both populations selected locations within their seasonal home range with no hunter access, and the strength of selection for locations with no hunter access was stronger in the archery season than the rifle season. However, individual models revealed that although third-order population-level selection for no hunter access was strong, only 43% of MRB elk selected for no hunter access during the archery season and 18% of elk selected for no hunter access during the rifle season. Additionally, the majority of all MRB elk locations (i.e., 68% of archery locations and 91% of rifle locations) occurred in areas accessible to hunters. In Larb Hills, individual models confirmed results of the population-level analysis, and 76% and 60% of elk selected for locations with no hunter access during the archery and rifle seasons. Even if hunter access is restricted or in a relatively small geographic area within an elk population range, elk refuge situations may have a disproportionate affect on elk distributions and prevent effective harvest of female elk to maintain elk populations at objective levels. Working cooperatively with stakeholders to minimize these situations is necessary for curtailing further elk population increases and maintaining a distribution of elk across public and private lands. If elk refuge situations cannot be resolved, stakeholders may need to choose between allowing some level of hunter access to harvest female elk or accepting higher numbers of elk, and associated property damage issues.

**Mexican Spotted Owl Site Occupancy Trends and Small Mammal Abundance in the Canyonlands of Utah

John Thornburg*, Ecology Department, Montana State University, Bozeman
David Willey, Ecology Department, Montana State University, Bozeman
Robert A. Garrott, Ecology Department, Montana State University, Bozeman

The Mexican Spotted Owl (*Strix occidentalis lucida*) is widely distributed in forest habitat from the central highlands of Mexico north to the four-corners region of the southwest U.S. However, in southern Utah, Mexican Spotted Owls are only found in arid rocky

canyonlands, e.g., ~30 owl pairs occupy narrow canyons within Zion National Park, and up to 10 territories occur in Capitol Reef National Park. We studied the owl's territorial occupancy and primary prey species in Capitol Reef and adjacent environs during 2000-2015. We recorded Spotted Owl territorial occupancy states, including absence, single, or owl pair (and we searched for young). At a sample of territories, we measured relative abundance of primary prey species (*Neotoma* and *Peromyscus* spp.) using mark-recapture techniques. We were specifically interested in Woodrats and White-footed Mice because they have been identified as the primary prey of Spotted Owls in rocky canyon habitat using pellet analysis. We successfully captured, marked, and released over 6000 small mammals of various species at five owl territories in Capitol Reef and three territories in Grand Staircase-Escalante National Monument (GSENM). We also recorded various habitat measurements at each small mammal trap location. Spotted Owl territorial occupancy varied strongly during 2000-2007 in GSENM, and during 2013-2015 in Capitol Reef. We observed that low site occupancy in GSENM was correlated with low relative abundance of prey species, and associated with a severe drought throughout the region. During 2013 and 2014 in Capitol Reef, we observed low owl occupancy, with only one occupied territory. During 2015, six extinct territories were re-colonized by Spotted Owls, however, small mammal abundance declined during 2013 to 2015. We will continue to measure long-term patterns among owl occupancy, prey relative abundance, vegetation changes and variation in climate.

**Seeking Out the Hoary Marmot: Habitat Characteristics of an Alpine Obligate

Ben Y. Turnock*, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman

Alpine ecosystems likely will be impacted by climate change, which will shift distributions of alpine species. To predict these shifts reliably, an increased understanding about the habitat characteristics that are important to alpine species will be necessary to manage for their continued presence on the landscape. We have very limited information about habitat for hoary marmots (*Marmota caligata*) in Montana. To address this knowledge gap, we investigated the relative importance of habitat characteristics for marmot occupancy. During the summers of 2014 and 2015, we surveyed 184 sites in 5 mountain ranges throughout western Montana. We surveyed each site 2-5 times (average = 4.25 surveys/site) and detected marmots in 61 sites using two survey methods. Wind speed, survey method, cloud cover, and percent of the site that was visible all influenced detection probability. We estimated that marmots occurred in 36% of all sites (95% CI = 29-46%). Occupancy of marmots increased with snow and shrub cover and decreased with slope and distance to water. Given that snowpack, precipitation, and water sources are predicted to be impacted by climate change, our results begin to illustrate where this species of concern may become susceptible. If snowpack and the number of water sources decrease or shift geographically, this may reduce or alter the available habitat for marmots. We hope to augment the paucity of information about hoary marmots at the southern end of their distribution and aid management of this species under an uncertain climate future.

**Developing Physiological Profiles using Nuclear Magnetic Resonance Spectroscopy to Inform Bighorn Sheep Management

Jesse R. White*, Department of Animal and Range Sciences, Montana State University, Bozeman
M. Rashelle Herrygers, Department of Animal and Range Sciences, Montana State University, Bozeman
Jennifer M. Thomson, Department of Animal and Range Sciences, Montana State University, Bozeman
Valerie Copie, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Brian Tripet, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Carson J. Butler, Ecology Department, Montana State University, Bozeman
Douglas E. McWhirter, Wyoming Game and Fish Department, Cody
William H. Edwards, Wyoming Game and Fish Department, Laramie
Kevin Monteith, Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie
Robert A. Garrott, Ecology Department, Montana State University, Bozeman
James G. Berardinelli, Department of Animal and Range Sciences, Montana State University, Bozeman

This study employs new techniques using nuclear magnetic resonance (NMR) to assess the relative health, physiological condition, and reproductive function of wild bighorn sheep (*Ovis canadensis*) in Montana and Wyoming. Ongoing bighorn studies in Montana and the Greater Yellowstone Ecosystem are focused on herd attributes and the population dynamics which are affected by disease, climate, habitat and physiology. Indices of herd health and physiological status are typically obtained through expensive and time consuming lab assays and field measurements. Recently, NMR spectroscopy has been used to revolutionize the assessment of human metabolic health, and we expect that there is similar potential for studies of wildlife populations. Using NMR spectroscopy to assess metabolites associated with disease, nutrition and stress may eliminate the need for many traditional assays and techniques used today. NMR can be used to evaluate a large suite of metabolites associated with a variety of physiological functions from as little as 500 μL of serum or plasma. Blood samples from 242 sheep from 13 different herds were collected during the winters of 2013-14 and 2014-15 to develop a comprehensive metabolite panel for bighorn sheep. We have used a recently developed statistical program known as MetaboAnalyst™ to begin to analyze and evaluate differences in NMR metabolic profiles among herds and across the fall-winter season when nutritional and physiological stress is expected to be acute. We will be presenting the results of this preliminary study and discussing the potential for application in wildlife management.

Poster Abstracts

**Optimizing Wildlife Monitoirng Strategies in a Dynamic Setting (Poster)

Charles R. Henderson Jr.*, Wildlife Biology Program, University of Montana, Missoula
Paul M. Lukacs, Wildlife Biology Program, University of Montana, Missoula
Mark A. Hurley, Idaho Department of Fish and Game, Boise

Long term, broadly distributed datasets are ideal for effective wildlife management. However, collecting and utilizing these data present a variety of challenges to management agencies. Idaho Department of Fish and Game is currently trying to optimize their use

of monitoring resources for mule deer (Odocoileus hemionus) throughout Idaho. Three areas are being investigated for their potential to accomplish this goal: cost effectiveness, data utilization, and efficiency in data collection. An analysis of the cost effectiveness of monitoring methods is currently being conducted. This analysis varies the amount of each type of data available to the population model used to estimate abundance. The precision, credible interval width (CRI), associated with the estimate is used as the measure of effectiveness, mean 95% CRIs range from 9278 - 9804. This measure of precision is then combined with the cost of the collection technique to compare the cost effectiveness of different monitoring methods. Further research will focus on a weighting scheme that weights data types by both sampling precision and reliability. Thereby allowing managers to fully utilize all available data sources based on relative quality within the framework of the population model. A third line of research focuses on increasing the efficiency of monitoring effort through an alternative sampling design derived from seasonal nutrition. The previous lines of research will then be combined to solve a dynamic programming problem to determine the optimal methods for monitoring population abundance while accounting for changes in the availability of monitoring resources over space and time.

Montana's Bat Acoustic Surveillance Efforts: an Update (Poster)

Shannon Hilty*, Montana Natural Heritage Program, Helena
Braden Burkholder, Montana Natural Heritage Program, Helena
Bryce Maxell, Montana Natural Heritage Program, Helena
Scott Blum, Montana Natural Heritage Program, Helena
Lauri Hanauska-Brown, Montana Fish, Wildlife, and Parks, Helena
Amie Shovlain, Beaverhead-Deerlodge National Forest, Dillon,MT
Jake Chaffin, Montana/Dakotas State BLM Office, Billings, MT

Montana's bat species face a wide array of conservation issues that threaten their long-term viability. A collaborative effort was initiated in 2011 to document year-round activity patterns of Montana's bats prior to the arrival of White-nose Syndrome as mortality has exceeded 95% for some bat populations effected by this disease in eastern North America. In the last 5 years, we have deployed a network of over 76 Song Meter ultrasonic acoustic detector/recorder stations programmed to record bat passes from sunset to sunrise year-round. Through late December 2015, these recording stations have resulted in more than 7.2 million full spectrum sound files containing nearly 13 terabytes of information. Processing and automated analyses have been completed for all sound files and over 43,000 bat passes have been reviewed by hand using an updated Montana bat call characteristics key to definitively confirm the presence of species during each month of the year, identify the lowest temperatures at which individual bat species are active, and track overall bat activity, regardless of species, at each station. Highlights to-date include: 2,104 new records of monthly species presence in various landscapes across the region, numerous first records of species' activity during the fall, winter, and spring months, numerous first records of species in regions with previously limited survey effort, documentation of nightly activity patterns throughout the year, regular winter activity for a few resident species, the year-round presence of species previously considered migratory, and exciting patterns of activity relative to temperature, wind speed, barometric pressure, and moonlight.

**Effects of Electric Fence Permeabiliy on Grizzly and Black Bears in the Blackfoot Valley of Montana (Poster)

Brittani Johnson*, Animal and Range Sciences Department, Montana State University, Bozeman
Lance McNew, Animal and Range Sciences Department, Montana State University, Bozeman
Jamie Jonkel, Montana Fish, Wildlife, and Parks, Missoula

Increasing agriculture-bear conflicts on private lands require innovative approaches to conserve wildlife while also conserving the economic viability of Montana farmers and ranchers. Electric fencing has been an effective tool for deterring bears from calving areas and bee yards. Recent advances in electric fencing materials, as well as automated deployment devices, have reduced costs and increased interest in using electric fencing to deter bears from larger areas, like crop fields. Scientific evaluations of the efficacy of temporary electric fencing at deterring grizzly (*Ursus arctos*) and black bears (*Ursus americanus*) are lacking. Additionally, large-scale installations of electric fencing may impact bear movements and habitat use. In 2015, we began a multi-faceted study in the Blackfoot Valley to evaluate A) the efficacy of various rapid-deployment electric fencing designs in deterring bears from agricultural lands, and B) landscape level space use and permeability of agricultural lands relative to electric fences. Baited enclosures of 2-3 fencing configurations were established in the valley during the spring of 2015. Each enclosure is systematically energized and unenergized for 3-day periods throughout the spring and summer; passage into the enclosure is monitored with motion-activated trail cameras to provide information on configuration effectiveness and permeability. In addition, we established 60 randomly selected camera trap stations throughout the valley to evaluate landscape-level habitat use relative to landscape metrics and electric fences. Daily movement locations provided by 5 grizzly bears fitted with GPS collars will provide individual-level information on seasonal movements and habitat selection relative to habitat conditions and electric fences.

Use of High-Resolution Aerial Imagery to Improve a GIS Habitat Model (Poster)

Debbie Leick*, MPG Ranch, Florence, MT

For many species, land cover is the most important input variable for a GIS habitat model. Yet, coarse-resolution satellite imagery provides the foundation of many available land cover datasets. With low-resolution imagery, habitats such as shrublands and narrow or small riparian elements typically remain invisible to digital image analysis software and to the naked eye. Habitat misclassification often occurs and land cover accuracy rates may range from only 60% to 80%. We ran a sharp-tailed grouse (*Tympanuchus phasianellus)* habitat model, originally developed by Montana FWP, using a current land cover layer based on 30-meter resolution satellite imagery. From the results, we chose a subset of areas with high potential to contain the most suitable habitat. We then updated each area's land cover by "ground-truthing" it against high resolution imagery (NAIP, 1 meter and Esri, 6 inch). We corrected misclassified habitats of interest and then reran the model. Although time consuming, we believe this manual "ground-truthing" process greatly improved the accuracy of the model and made the on-ground habitat surveys more efficient. We also believe this approach would improve habitat modeling efforts for other species.

Accessing Information on Montana's Animals, Plants and Biological Communities Through the Montana Natural Heritage Program's Web Applications: Recent Updates (Poster)

Bryce Maxell*, Montana Natural Heritage Program, Helena
Dave Ratz, Montana Natural Heritage Program, Helena
Karen Coleman, Montana Natural Heritage Program, Helena
Linda Vance, Montana Natural Heritage Program, Helena
Andrea Pipp, Montana Natural Heritage Program, Helena

The Montana Natural Heritage Program (MTNHP) was established by the Montana State Legislature in 1983 and charged with statutory responsibility for acquisition, storage and retrieval of information documenting Montana's flora, fauna and biological communities (Montana Code Annotated 90-15). Information managed by MTNHP includes taxonomy, biology, ecology and conservation status information for nearly 8,000 plant and animal species and nearly 150 terrestrial and aquatic communities, nearly 1.7 million animal observation records, over 182,000 locations where a formal structured animal survey protocol has been followed, predictive distribution models for animal and plant species, species occurrence and wetland and riparian mapping polygons that are used in environmental reviews, land cover mapping and land management information. We deliver this information via staff facilitated requests and web applications that include the Montana Animal and Plant Species of Concern reports, the Montana Field Guide, the Natural Heritage MapViewer and the Species Snapshot. In this presentation we will provide a brief overview of how biologists and natural resource managers can access information via our websites. We will focus on recent updates to our Species Snapshot and Montana Field Guide applications that allow users to create custom species summaries and field guides using spatial, taxonomy and conservation status filters and our vision for the development of an environmental review tool that can be used by agency resource managers, planners and consultants to speed environmental reviews.

**Age Determination of Live-Captured Beavers by Weight in Southwest Montana (Poster)

Ashley E Micklewright*, Department of Ecology, Montana State University, Bozeman
Torrey Ritter, Department of Animal & Range Sciences, Montana State University, Bozeman
Lance McNew, Department of Animal & Range Sciences, Montana State University, Bozeman

Studies evaluating demography and agespecific space use of beavers (*Castor canadensis*) require accurate methods for aging livecaptured individuals in the field. Unfortunately, techniques for aging livecaptured beavers in the field are often unreliable and can require previous experience in handling beavers. Previous ageweight relationships developed in other regions (e.g., Midwest) may not be suitable, because differences in diets, seasonal behavior, and selection for lifehistory traits likely results in significant regional variation in ageweight relationships. Thus, regional assessments of age-weight relationships are necessary for accurate inference. In the fall of 2015, we began a two-year study with the goal of developing accurate growth curves for beavers occurring in southwestern Montana. We are collecting beaver carcasses from local trappers and animal control experts. Carcasses are weighed and the molar teeth extracted for laboratory analysis of cementum annuli which provide an accurate age for each beaver. Regression analysis will be used to model ageweight relationships for beavers, and model predictions will be tested using a holdout dataset and crossvalidation. We expect our results to provide useful information for researchers in forested headwater habitats of Montana, and provide baseline data for calibrations for broaderscale assessments in the region. Please contact us if you can provide whole beaver carcasses.

Influence of Boulder Size on Occupancy and Detection of Hoary Marmots (Poster)

Aubrey R. Power *, Ecology Department, Montana State University, Bozeman
Ben Y. Turnock, Ecology Department, Montana State University, Bozeman
Andrea R. Litt, Ecology Department, Montana State University, Bozeman

Hoary marmots (*Marmota caligata*) can be found in boulder fields throughout alpine areas of western Montana, but we know little about their specific habitat requirements. We sought to determine the influence of boulder size on occupancy and detection probability of the hoary marmot during occupancy surveys. We conducted 532 visual occupancy surveys of 147 sites between June and September 2015. We estimated variation in occupancy and detection probability based on four size categories of boulders. We did not detect differences in occupancy of marmots as the size composition of boulders changed. Detection probability was most influenced by medium and large boulders. Probability of detecting a marmot was 38% (95% CI=0.24–0.53) when medium boulders were absent, but decreased to 3% as the proportion of medium boulders increased to 60% (95% CI=0–0.15). Probability of detecting a marmot was 16% when large boulders were absent (95% CI=0.1–0.24) but increased to 92% when just 5% of the site consisted of large boulders (95% CI=0.61–0.99). Accounting for this variation in detection probability with changes in boulder size will be important for designing a long-term monitoring protocol that can produce accurate estimates of occupancy for hoary marmots. A monitoring protocol incorporating key habitat requirements would be valuable for the future management and conservation of a species living in harsh alpine environments where climate change is predicted to occur rapidly.

**Habitat Selection, Movements and Survival of Dispersing Juvenile Beavers in Southwestern Montana (Oral and Poster)

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

The natural activities of beavers (*Castor canadensis*) effectively create or expand, and maintain, healthy riparian and wetland areas. Therefore, interest has increased among land and wildlife managers in the reintroduction of beavers into degraded riparian habitats as a proactive management option for natural restoration of these areas. However, there is a need for information regarding habitat selection by beavers in novel habitats to increase the likelihood that reintroduced beavers will colonize the area targeted for restoration. We are using cable snares to capture and radio tag dispersal age beavers in headwater streams of the Madison and Gallatin River drainages. We will relocate tagged beavers via handheld telemetry to obtain movement data from the moment the beavers leave their natal colony in the spring until they settle in a new location in the late summer and fall. Habitat characteristics representing vegetation, hydrology and geomorphology will be assessed at settlement locations as well as locations encountered but not settled to make inference on habitat conditions most important to dispersing beavers in selecting settlement sites. Eighteen beavers were radio tagged in the fall of 2015 representing 6 different streams in the study area. The 18 tagged beavers will be tracked through the spring and summer of 2016 and habitat conditions will be assessed based on their movements before another season of beaver trapping in the fall of 2016. Our analysis of habitat selection by juvenile beavers will guide future beaver restoration projects in this region by identifying release sites with the highest probability of success.

**Bats in Buildings: Assessing Human Structures as Roost Sites in Glacier National Park (Poster)

Cheyenne E. Stirling *, Department of Ecology, Montana State University, Bozeman
Andrea R. Litt, Department of Ecology, Montana State University, Bozeman
Lisa Bate, Glacier National Park, West Glacier, MT

Many bat populations are declining due to factors such as spread of white-nose syndrome (WNS) and changes in land use, increasing the need for information to prevent further declines. The little brown bat (*Myotis lucifugus*) is a species of concern in Montana, is susceptible to WNS, is the most common bat in Glacier National Park (GNP) and is frequently found roosting in buildings. We sought to document the locations and types of bat roosts in human structures throughout GNP. We conducted daytime inspections of 579 of the >900 buildings in GNP during summer 2015. When we detected a roost, we determined whether it was a day or night roost and recorded characteristics of the building and roost. In total we found 451 roost sites; most were night roosts. Buildings with tin siding were less likely to be used as night roosts, whereas buildings with masonry were more likely to be used as night roosts. Buildings with a bat house were more likely to be used as day roosts. We also found some evidence that bats preferred to day roost in buildings with tin roofs or logs. These baseline data on locations and numbers of bat roosts will allow biologists to better assess potential impacts of WNS should it arrive in Montana. These data also will provide GNP staff with the necessary information to develop mitigation measures to protect bats.

**Grizzly Bear Use of Forest Service Grazing Allotments in The Greater Yellowstone Ecosystem (Poster)

Smith L. Wells*, Animal and Range Sciences Department, Montana State University, Bozeman,
Lance B. McNew, Animal and Range Sciences Department, Montana State University, Bozeman
Daniel B. Tyers, U.S. Forest Service, Northern Rocky Mountain Science Center, Bozeman, MT

Range expansion of the Greater Yellowstone Ecosystem (GYE) grizzly bear (*Ursus arctos*) population has led to increased human-bear conflicts, including livestock depredation. In 2015, we began a study to evaluate spatio-temporal patterns between public land livestock grazing, grizzly bear habitat use and livestock depredations. In collaboration with the U.S. Forest Service and the Interagency Grizzly Bear Study Team, we will obtain 25 years (1989-2014) of data related to Forest Service grazing allotments, including livestock stocking and on-off dates, locations of individual collared bears, grizzly bear depredations and management removals, bear density and habitat characteristics pertinent to bear space use (e.g. landcover, elevation, human activity) within the GYE. Bear and conflict locations will be related to allotment information, habitat characteristics, and bear density using generalized linear models to evaluate what factors are influencing grizzly bear space use and depredation events, and how they have changed across seasons and years. Habitat selection by individual bears will be evaluated at two scales, home range selection within the landscape and selection within the home range, to give more insight into factors affecting space use and how they differ among individual bears. Our results should facilitate the development of adaptive approaches to conserve grizzly bears while also conserving the economic viability of livestock operations, and should have utility for bear and land management in the GYE.

Montana Academy of Sciences

2016 Annual Meeting

April 8-9, 2016

Montana Tech of the University of Montana - Butte, Montana

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

INTRODUCTION

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

We held our 2016 Annual Meeting at Montana Tech in Butte, MT. on April 8 and 9. Over 100 registrants participated, viewing 13 contributed oral presentations and 13 poster presentations over the day and a half meeting. We present the abstracts from our meeting here so that the readers of the Intermountain Journal of Sciences can see the quality and types of science supported by MAS. Please mark your calendars for our next meeting, April 7 and 8, 2017 in Butte. Finally, the Board of Directors of MAS would like to thank the sponsors of our 2016 Annual Meeting:

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

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

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

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

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

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

.

Presentation Abstracts

Alphabetical by First Author's Last Name

Corrosion Inhibition: The Investigation of Lanolin on the Corrosion of 1018 Carbon Steel in Commercial Sea Water

Stephen Broddy, Montana Tech, Butte

There is a high demand for an environmentally friendly and cost-effective corrosion inhibitor. Due to the relatively low viscosity (high capillary action), commercially available polymeric lanolin has been used as a biodegradable corrosion inhibitor in addition to a natural lubricant for marine steel applications. In this work, corrosion of lanolin-saturated 1018 steel was investigated while completely submerged in stagnant seawater under local atmospheric conditions. Samples were immersed in commercial sea salt solution and analyzed at regular intervals. Determination of corrosion rate change, hardness variation and variation in surface microstructure of each specimen was executed on both standard and lanolin-treated 1018 steel specimens. At this point in the work, lanolin-treated 1018 steel samples retain polymeric coat and infer a high resistance to corrosion under long-term submersion. SEM-based analysis has inferred substantial corrosion attack occurring at the standard sample periphery compared to lanolin-treated samples. The addition of lanolin to the surface of the sample displayed a relatively low consistency in corrosion rate calculations compared to the standard sample.

Stormwater in Silver Bow and Blacktail Creeks: Implications for the Microbial Community

Jordan Foster, Chemistry and Geochemistry Department, Montana Tech, Butte
Dr. Alysia Cox. Chemistry and Geochemistry Department, Montana Tech, Butte

Silver Bow and Blacktail Creeks are the headwaters of the Clark Fork River and are impacted by historic mining activities in the area. Although metal concentrations of runoff into the creeks are monitored and reported in previous studies, the composition and diversity of microbial communities are unknown. We seek to identify the microbial communities present and investigate changes in community structure due to stormwater impact, thereby determining and monitoring the overall environmental health of the system. We sampled five sites in Silver Bow and Blacktail Creeks in Butte, MT for chemical and biological analyses during high stormwater flow events. Water samples were collected for analysis of major anions and cations, metal concentrations, dissolved inorganic and organic carbon and carbon isotopes and hydrogen and oxygen isotopes in water. In situ measurements of pH, temperature and dissolved oxygen were taken at the time of sampling. Redox sensitive species - total dissolved sulfide, dissolved silica and ferrous iron - were measured using wet chemical tests and field spectrophotometry. Concurrent biological samples were collected for microbial identification and diversity (DNA), activity (protein), quantity (cell counts) and culturing. Overall microbial results are in progress, but water chemistry data provide clues about microbial habitats available in the creeks. Results upstream in Butte will be compared to downstream areas such as Durant Canyon and the Warm Springs Settling Ponds. The relationship between water chemistry, microbes, and overall ecosystem health can be characterized by deciphering how water chemistry affects microbial activity and vice versa.

Touchless Thermal Respiratory Monitor

Robin Hallett, Electrical Engineering, Montana Tech, Butte
Jonathan Schulz, Electrical Engineering, Montana Tech, Butte

An abnormal respiratory rate and changes in respiratory rate can give an early indication of physiological disorders such as a stroke or heart failure. Also, many drugs prescribed for pain or sedation carry the risk for respiratory depression. Medical devices used to track breathing today often require the use of wires and sensors that can create obvious restrictions in the patient's motion, ability to maneuver, or even sleep. The long-term objective of this research project is to build a system that can monitor breathing without coming into contact with a patient. The goal of the current project is to optimize the functionality of the sensor and prove functionality by testing on human subjects. The Touchless Thermal Respiratory Monitor was built using a thermal sensor, 3-D printed parts, and a laser. The thermal sensor was programmed to read temperature, and in this project, the location yielding the greatest temperature differential between the air that has been exhaled by the patient and the room temperature will be found. The laser will allow for proper alignment of the thermal sensor to this location. The temperature difference will be monitored and plotted in MATLAB in order to track the respiratory rate. Irregular signals or a lack of signal would indicate that the patient is having breathing problems, or that the patient has moved out of the sensors path.

Nuclear Magnetic Resonance Spectroscopy Metabolic Profiles to Distinguish Geographically Isolated Populations of Mountain Goats

M. Rashelle Herrygers, Department of Animal and Range Sciences, Montana State University, Bozeman
Jesse R. White, Department of Animal and Range Sciences, Montana State University, Bozeman
Jennifer M. Thomson, Department of Animal and Range Sciences, Montana State University, Bozeman
Valerie Copie, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Brian Tripet, Department of Chemistry and Biochemistry, Montana State University, Bozeman

Basic physiological studies on mountain goats (*Oreamnos americanus*) are conspicuously lacking in the literature, and the physiology of this species is perhaps the least known of the high mountain ungulates. The objective of this study was to evaluate metabolic profiles of female mountain goats from five geographically distinct populations using Nuclear Magnetic Resonance (NMR) spectroscopy. Serum samples were collected from nannies located in Alaska in September (AK) from Glacier in August (GMT), from the Grand Tetons in November-December (GT), from NE Yellowstone in December (NEY) and from Absaroka in March (AB). Serum was extracted with acetone, dried and re-suspended in a standard NMR buffer. NMR spectra were analyzed with Chenomix™ software. Metabolites were identified and concentrations determined using the Chenomix™ database and the Human Metabolome Database. We identified 55 metabolites in the serum of mountain goats using this emerging technology. Of these 42 metabolites differed among the herds ($P < 0.05$). Of these 42 metabolites; creatinine, lactate and pyruvate distinguished ($P < 0.05$) each herd from another. Furthermore, using Principal Component Analyses of these metabolites allowed us to clearly differentiate metabolic profiles in carbohydrate, protein and lipid metabolism in nannies from these five populations. This study has the potential to enhance our understanding of how changes in nutrition, reproduction, susceptibility to disease, and survival rates drive population dynamics.

Isolation of Essential Oils from Indigenous Montana Flora and Their Antimicrobial Effectiveness as a Non-Toxic Sterilizing Reagent Against Bacteria that Cause Food Borne Illness

Samantha Miner, Chemistry Department, Montana Tech, Butte
Dr. Katie Hailer. Chemistry Department, Montana Tech, Butte

Bacterial resistance and the negative effects of chemicals used to kill them have become a growing worldwide public health concern. The widespread use of antibiotics in medicine and animal husbandry have caused bacteria adaptation to antibiotics. New drug discovery has become vital in fighting the war against drug-resistant bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Salmonella epidermis*, which have posed considerable medical problems. Essential oils are a safe, generally non-toxic and relatively inexpensive alternative to synthetic chemical based antibiotics. Essential oils hydro-distilled from indigenous Montana flora will be explored for their antimicrobial effectiveness as a non-toxic sterilizing reagent against bacteria. We hypothesis that the oils of *Lomatium dissectum*, *Arctostaphylos uva-ursi* (L.), *Chimaphila umbellate* (L.), W. Bart *Prunella vulgaris* L , *Artemisia dracunculus* L, *Spreng Medicago lupulina L*., and *Balsamorhiza sagittata* will have significant anti-bacterial properties and variability that works to reduce bacterium's resistance.

Piezoelectric Energy Harvesting System

Chau Duc Minh Ha, Geophysical Engineering Department, Montana Tech of the University of Montana, Butte

This project investigates the behavior of two types of piezoelectric harvester in response to different applied strains. Three tests are performed: two Deflection Amplitude vs. Voltage Generation tests and an Energy Charging Rate test. The two deflection tests are done on a Volture energy harvester and a piezoelectric disk. The energy charging rate test is done on a pair of piezoelectric disks. The strain test on the Volture energy harvester show inconsistent relationships between a piezoelectric harvester's natural frequency and its ability to generate voltage. The strain test on the piezoelectric disk are also not clear either since the voltage generated varies greatly after each tap. The results from the energy charging rate test indicate that a piezoelectric harvester generates energy at a higher rate when subjected to a higher-frequency vibration source than to a lower-frequency one. Future studies are recommended to make comprehensive conclusions regarding the relationships between a piezoelectric harvester's natural frequency and its ability to generate voltage. Further researches regarding vibration sources are also recommended as finding a suitable vibration source is found to be the most challenging part of this project.

The Association of Lexile Level and Reading Comprehension While Multitasking

Colin Norick, Columbia Falls High School, Columbia Falls, MT

The purpose of this study is to provide data to examine the use of cellphones, specifically texting, in relation to reading comprehension, and analyzing the relationship with Lexile scores. The Lexile framework quantifies reading comprehension of the reader and of the text. Initially, 47 participants completed leveled reading comprehension tests, one without texting and one while texting. Students performed 9% worse on reading comprehension while texting

compared to non-texting and performed 6% worse on long-term memory questions on the material while texting. We conclude this is due to increasing the cognitive load by texting. As a follow up, 57 participants texted during both tests, one test at their Lexile and one test at a Lexile 250L lower. Participants performed 56% better on reading comprehension when the material was 250L below their level and 28% better on long-term memory questions. Overall, texting while completing reading comprehension tests had an adverse impact on performance, but decreasing the Lexile led to a statistically significant improvement over what should be expected through just decreasing the Lexile score by decreasing the cognitive load These results identify this relationship for more research and eventually might affect what reading level textbooks are written at to increase comprehension.

Indices of Body Composition and Repeatability of Residual Feed Intake in Growing Columbia Ewes Fed the Same Diet

Katharine A. Perz, Department of Animal and Range Sciences, Montana State University, Bozeman
James G. Berardinelli, Department of Animal and Range Sciences, Montana State University, Bozeman
Lauren N. Park, Department of Animal and Range Sciences, Montana State University, Bozeman
Robin K. Pollard, Department of Animal and Range Sciences, Montana State University, Bozeman
Chad M. Page, Department of Animal and Range Sciences, Montana State University, Bozeman

Residual feed intake (RFI), an efficiency measurement based upon the difference in expected and actual feed intake, is used to improve production efficiency of livestock. The purpose of this study was to evaluate the repeatability of ewe RFI measured for two consecutive years, and to investigate the relationship between indices of body composition in yearling ewes and RFI. Two trials, using the same Columbia ewe lambs (n = 17) were conducted in consecutive years (2014, 2015) using the same diet. RFI was calculated for each ewe each year. RFI did not differ (P = 0.77) between years. Each year, ewes were separated into RFI classes (LOW (efficient); MOD (average); HIGH (inefficient)). In 2014, ewe lamb performance did not differ among classes (P > 0.3). In 2015, dry matter intake was greater for HIGH ewes (P < 0.0002). Ribeye area (REA; cm^2) and backfat thickness (BF; cm) were measured by ultrasound on day 0 (start of trial), 17, and 45 (end of trial) in 2015 and used to calculate estimates of final body composition. RFI classification did not affect REA or BF (P > 0.25). There was a trend for whole-body muscle mass to differ among RFI classes (P = 0.09), but no other body composition estimates were affected. Results suggest that RFI is repeatable; however, indices of body composition seem to be independent of RFI in Columbia ewes fed the same diet under similar conditions.

Properties of 3D Printed PLA with Additives

Lucas Reif, Montana Tech, Butte

As the technology of 3D printing increases rapidly in today's world, so too does the list of properties desirable in a finished, printed project. One way to improve said properties is to include additives in the material a 3D printer utilizes. The research program combined talc and mica with the PLA plastic presently used in many 3D printers. The end purpose was to measure the additives' effects on the strength and other properties at different additive proportions. The behavior of the new PLA printing filament was evaluated so that an optimal additive amount could be recommended.

Information Technology use at Montana Tech

Lance Revenaugh, Montana Tech, Butte
Gunnar Kayser, Montana Tech, Butte
Hunter Gappmayer. Montana Tech, Butte

In today's world, there is something very valuable that is ever changing and advancing every single day. That is technology. More specifically, the use of technology in educational settings, such as colleges and universities, has advanced phenomenally in the last fifteen years. Students, along with faculty/staff alike have been branching out and exploring new advances in technology for both personal and educational use. The purpose of our project was to find a connection between educational and personal usage of technology in students along with faculty and staff. With that, we plan to create an annual survey issued to both students and faculty, to ultimately find better ways to utilize technology in education for the population at Montana Tech.

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

Anthony Slominski, Department of Ecology and Environmental Sciences, Montana State University, Bozeman

Climate-warming is causing shifts in seasonal flowering periods and pollinator emergence dates (i.e., phenologies) that are species-specific in magnitude and direction, which has altered the amount of phenological overlap between coevolved plant and pollinator species. The objective of this project was to experimentally investigate the effects of such phenological shifts on plant-pollinator interactions and plant and pollinator reproductive success. To achieve this, I controlled the phenologies of forbs and solitary bees such that spring and summer flowering forb species flowered at the same time and spring and summer emerging bees emerged at the same time. Blooming forbs and emerged bees were then placed in mesh-sided enclosures following a factorial design based on their phenological life histories (i.e., spring or summer). Forb-bee interaction patterns were assessed by conducting bee visitation observations and documenting the quantity and duration of bee visits to flowers. Plant reproductive success will be determined by quantifying the number and mass of seeds produced for each plant species. Bee reproductive success will be assessed by determining the identity and quantifying the number of offspring produced in bee nests housed within each enclosure. Empirical evidence generated by this study will elucidate underlying mechanisms driving the effects of climate change on plants and pollinators and will help pinpoint plant and pollinator species most vulnerable to the negative effects of climate change. Results will contribute to a better understanding of the ecological effects of climate change on species interactions and inform conservations strategies.

18-Beta-Glycyrrhetinic Acid Causes Increased Pigment Production and Decreased Adherence in Methicillin Resistant Staphylococcus Aureus Biofilms

Alan J. Weaver, Jr., Dept. of Chemistry & Biochemistry, Montana State University, Bozeman
Abigail Van Vuren, Dept. of Chemistry & Biochemistry, Montana State University, Bozeman
Dr. Valerie Copie, Dept. of Chemistry & Biochemistry, Montana State University, Bozeman
Dr. Martin Teintze, Dept. of Chemistry & Biochemistry, Montana State University, Bozeman
Dr. Mary Cloud B. Ammons, Dept. of Chemistry & Biochemistry, Montana State University, Bozeman
Dr. Jovanka Voyich, Dept. of Microbiology & Immunology, Montana State University, Bozeman

Infections caused by Methicillin Resistant Staphylococcus aureus (MRSA) are an ever growing concern in the health care field. While MRSA is most known for its resistance to beta-lactams (i.e. penicillin), it has also acquired resistance to a number of other antibiotics. MRSA plays a major role in chronic wounds due to its ability to form a biofilm, resulting in severe infections. Biofilms are naturally more resistant to antibiotics than planktonic cells which can be due to their extracellular polymeric substance and slow growing nature, as well as metabolic differences. This has resulted in biofilms becoming a major focus in the biomedical field. As MRSA rapidly acquires resistance to currently available antibiotics, there is an urgent need to develop novel antimicrobials. 18β-Glycyrrhetinic acid (GRA) is a compound isolated from *Glycyrrhiza glabra* and has been shown to be an effective antimicrobial against Staphylococcal planktonic cells; however, investigations on biofilm activity appear to be lacking. Our studies show GRA to have minimal to no effect on biofilm bacterial counts; however, post-treatment observations included an increase in yellow pigment and decreased adherence of biofilms. S. *aureus* pigments play an important role in virulence, including oxidative stress that may be introduced by antimicrobials like GRA. Crystal violet staining of GRA treated biofilms showed a quantified reduction in adherence compared to controls. This suggests that GRA may cause biofilm dispersal and therefore increased susceptibility to current antimicrobials. 1H NMR metabolomics is being conducted to investigate these results and other metabolic changes in GRA treated biofilms.

Toxicity of Ammonia and Nitrite to Aquatic Macroinvertebrates

W. Tom Willingham, Dept. of Chemistry, Montana State University, Bozeman
Robert V. Thurston, Dept. of Chemistry, Montana State University, Bozeman
Robert J. Luedtke, U.S. Environmental Protection Agency, Office of Research and Development, Athens, GA
Rosemarie C. Russo. U.S. Environmental Protection Agency, Office of Research and Development, Athens, GA

The acute toxicity of ammonia was studied for six aquatic macroinvertebrate species (mayfly, stonefly, and caddisfly families). Two partial-chronic (24- and 30-day) tests were conducted on *Pteronarcella badia*. The acute toxicity of nitrite was studied for seven species, including one Diptera species; the mitigating effect of chloride ion on nitrite toxicity to two species was also investigated. For 6 tests on ammonia the median lethal concentration (96-hour LC50) values ranged from 1.8 to 5.0 mg/L un-ionized ammonia (NH3); in 19 tests less than 50% of the larvae died at the highest test concentration, so an LC50 could not be calculated. In the partial-chronic tests on P. *badia*, food consumption was not affected at concentrations up to 6.9 mg/L NH3, but concentrations in excess of 3.4 mg/L NH3 adversely

affected nymphal survival rates and emergence of adults. For nitrite toxicity, test results showed a wide range of tolerance. The 96-hour LC50 for the single species of Diptera exceeded 123 mg/liter NO2-N; the 96-hour LC50 range for the other tests was between 0.25 and 2.4 mg/liter NO2-N. The addition of 10 mg/liter chloride ion in nitrite tests on P. *badia* and *Ephemerella grandis* resulted in a 3- to 10-fold decrease in 96-hour LC50 values. The tolerance to ammonia of the most sensitive of the insect species tested was greater than that reported in the literature for most species of fishes. Except for A. *variegata*, the range of acute toxicity of nitrite to the insects tested was similar to that reported for fishes.

Poster Abstracts

Alphabetical by First Author's Last Name

The Effects of a Large River Impoundment on River Channel Complexity: Implications for Macroinvertebrate Community Structure (Poster)

Niall Clancy, Montana State University, Bozeman
Eric Scholl, Montana State University, Bozeman
Wyatt Cross, Montana State University, Bozeman

Nearly all major rivers are affected by impoundments or other forms of flow regulation. Downstream of dams, river geomorphology is often altered by changes in sediment load and flow regime, which may influence key habitats for biota. Our study examined the impact of Fort Peck Dam on downstream habitat complexity (i.e. proportion of off-channel habitats), and associated macroinvertebrate communities in the Missouri River, MT. We used aerial imagery and GIS software to quantify habitat complexity at four sites between Fort Peck Dam and Lake Sakakawea. Additionally, macroinvertebrates were sampled in the main channel and off-channel habitats in April and July 2015 at the same locations as habitat quantification. Following sampling, macroinvertebrates were taken to the laboratory where they were counted, identified to the lowest practical taxonomic level (usually genus), and measured to the nearest millimeter to estimate biomass using length-mass regressions. Preliminary data indicate that the number and area of off-channel habitats were significantly reduced immediately beneath the dam. Additionally, off-channel habitats contained unique macroinvertebrate communities that had higher abundance and biomass estimates compared to macroinvertebrates in the main-channel. These communities were primarily dominated by oligochaetes and chironomid midges.

Snorkel Research on Anadromous Fishes (Poster)

Conner Holbrook, Dept. of Biological and Physical Sciences, Montana State University – Billings
Kim Apperson, Idaho Fish and Game, Boise
Matthew Amick. Idaho Fish and Game, Boise

Dam construction has had a large impact on anadromous fish in the Pacific Northwest. All anadromous salmonids in the Pacific Northwest have been deemed as endangered species. In addition, climate change, and commercial and sport fishing have also had an impact on the anadromous populations. As a result, state and federal organizations have made an effort to augment populations with hatcheries, habitat restoration, and improved fish passages through dam systems. In efforts to understand the tributaries and spawning grounds used by chinook

salmon and steelhead trout, the Idaho Department of Fish and Game has created population research groups in the form of snorkel crews. One goal of the snorkel crew was to gain a better understanding of which tributaries are frequented by each species of fish. Snorkel transects consisted of regular sites that were snorkeled annually, as well as sites chosen at random. Transects were lengths of water from 65 to 200 meters long. Snorkelers moved in a serpentine pattern through the stream to cover maximal area. Fish size, number and species were recorded only after fish were passed by a snorkeler. Periodically, the snorkeler would relay data to a person nearby designated to data collection. Sites were chosen at random to be evaluated using a mark re-sight method to estimate efficiency. Anglers fished an area, caught fish were marked and recorded and then released. After fishing the site was left untouched for at least 24 hours before it was snorkeled. After snorkeling an in depth habitat evaluation was conducted.

The Intertwined Successional Development of the Lamb Gut Microbiota And Immune System (Poster)

M. M. Lachman, Department of Animal and Range Sciences, Montana State University, Bozeman
S. Ishaq, Department of Animal and Range Sciences, Montana State University, Bozeman
S. Olivo, Department of Animal and Range Sciences, Montana State University, Bozeman
M.R. Herrygers, Department of Animal and Range Sciences, Montana State University, Bozeman
J. Swartz, Department of Animal and Range Sciences, Montana State University, Bozeman

Gastrointestinal tract (GIT) microbes play critical roles in host nutrition, health and immunological development. For adult ruminants, GIT-dwelling microbes provide ~70% of daily energy requirements. The GIT also houses 70 % of the animal's immune system in the form of the Gut-associated Lymphatic Tissue (GALT), which houses 80% of all plasma cells and depends on microbial stimulation for maturation. Because nutrition and disease are two major factors in the economic sustainability of livestock production, our group set out to characterize the successional development of GIT microbiota and immune activity. Blood and GIT samples were collected from lambs immediately at birth through one-year of age, and from the dam's vagina, mouth, and rectum at parturition. Blood samples were profiled for serum titers of IgM, IgA and IgG, while microbiota were profiled in GIT samples by 16S rRNA gene sequencing. Lamb GIT microbiota initially resembled the dam's vaginal microbiota but following exposure to the dam, became rapidly more similar to the dam's teat. GIT samples eventually formed stable climax communities similar to the dams around 180 days of age. This corresponded to the peak serum titers for each immunoglobin, which, aside from a peak in IgG at birth (likely colostral transfer), had gradually increased prior to this time. Immunoglobins peaked and then return to a sub peak level between 180 and 365 days. These results indicate dam vaginal microbiota have a short-lived impact on the neonatal microbiota, with the GIT microbiota going through a dynamic successional development to 180 d when immune function appears to peak.

Determining the Place of AQP-3B in the WNT/CA2+ Noncanonical Pathway (Poster)

Oscar Machado, Cell Biology and Neuroscience Department, Montana State University, Bozeman
Jennifer Forecki, Cell Biology and Neuroscience Department, Montana State University, Bozeman
Christa Merzdorf, Cell Biology and Neuroscience Department, Montana State University, Bozeman

During *Xenopus laevis* gastrulation, convergent extension is required for the mesoderm to extend into the embryo and shape the embryonic body plan. Recent results from our lab suggest that the inhibition of aqp-3b prevents convergent extension of the mesoderm and that aqp-3b acts through noncanonical Wnt signaling. Wnt signaling is a key signal pathway for embryo and tissue development. There are two types of Wnt signaling pathways, the canonical and the noncanonical pathways. There are three separate branches to noncanonical Wnt signaling. Our lab has shown that aqp-3b acts through the noncanonical Wnt/Ca2+ pathway and that it acts upstream of the cytoplasmic Wnt signaling pathway member Disheveled. The Frizzled7 membrane receptor is part of the noncanonical Wnt/Ca2+ pathway and also acts upstream of Disheveled. I will test, whether in this signaling cascade, aqp-3b acts upstream or downstream of Frizzled 7. Thus, I will test whether Frizzled 7 activates aqp-3b, if aqp-3b activates Frizzled 7, or if aqp-3b is bypassed and Frizzled 7 activates disheveled. When Frizzled 7 is active, GFP-labeled protein kinase C (PKC-GFP) relocates from the cytoplasm to the plasma membrane. Thus, I will inject either PKC-GFP alone, PKC-GFP + fz7, or PKC-GFP + fz7 +aqp-3bMO (to inhibit aqp3b) into two-cell *Xenopus* embryos and examine under a fluorescence microscope whether the PKC is bound to the membrane (Wnt signaling active) or remains in the cytoplasm (no Wnt signaling). With this procedure the place of aqp-3b within the Wnt/Ca2+ pathway will be determined.

CRISPR/CAS9 Gene Editing to Study Mammalian Iron Transport and Iron Homeostasis (Poster)

Katy Martin, Biochemistry, Montana State University, Bozeman
Sarah Bloch, Biochemistry, Montana State University, Bozeman
Martin Lawrence, Biochemistry, Montana State University, Bozeman

The CRISPR-Cas9 gene editing system is a 2 component system that utilizes the Cas9 protein and a sgRNA to target and knock-out a desired gene. The target gene is physically mutated by creating a double strand break in the DNA sequence of the targeted portion of DNA. Subsequent repair of the double strand break by cellular machinery typically leads to insertions or deletions (indels) that disrupt the gene, such that the gene is rendered nonfunctional. We are using CRISPR-Cas9 to knock-out genes involved in mammalian iron transport, specifically those of the transferrin cycle. Our first target is Steap3, a transmembrane ferric-reductase that reduces Fe(III) to Fe(II) for subsequent transport across the membrane into the cell by DMT1 (Divalent Metal Iron Transporter 1). Our specific strategy for the CRISPR/Cas9 knock-out of Steap3 and our progress towards this goal will be presented.

Characterization of the Effects of Small Molecules on Mountain Pine Bark Better Fungal Symbionts (Poster)

Stephanie Maxwell, Dept. of Biological and Physical Sciences, Montana State University, Billings
Joy Goffena, Dept. of Biological and Physical Sciences, Montana State University, Billings
David Butler, Dept. of Biological and Physical Sciences, Montana State University, Billings
Kurt Toenjes, Dept. of Biological and Physical Sciences, Montana State University, Billings

Several species of the bark beetle, in particular the Mountain Pine Beetle (*Dendroctonus ponderosae*), are responsible for killing large numbers of trees over vast areas in western North America, including over 31 million trees in Montana. Most or all of these bark beetle species are host to a variety of ophiostomatoid fungi. Many of these fungi are carried in the mycangia, a specialized structure of the exoskeleton, and are critical nutritional mutualists to the beetle's life cycle. Thus, one possible means of controlling or managing a beetle outbreak is to inhibit the growth of their associated fungi. These fungal spores are also indirectly introduced to the tree interior where they invade the phloem and sometimes the xylem of the tree that can possibly disrupt the water flow. Therefore, another possible prevention method might be inhibiting the fungi from mycelial growth on the tree itself. The first stage of this research is to test whether small molecule inhibitors are able to prevent growth for the fungal species associated with mountain pine beetles, (*Grosmannia clavigera* and *Ophiostoma montium*). The fungal species have shown sensitivity to the small molecule inhibitor, BH3I, especially G. clavigera. Because BH3I has potent antifungal activity, we will test its derivatives in hopes of finding additional small inhibitor molecules to effectively obstruct fungal growth. We can then begin testing different concentrations of the effective small molecules on the fungi, and furthermore, we can develop a tree-like environment to begin examining the effects of the inhibitors on the xylem and phloem of trees.

Screening Montana Native Grass Species for Resitance to Spotted Knapweed Exudate Catechin (Poster)

Christopher Prescott, Rocky Mountain College, Billings, MT
Dr. Mark Osterlund, Rocky Mountain College, Billings, MT

It has been reported that catechin is an exudate of spotted knapweed (*Centaurea maculosa*). Documented to have chelating, antimicrobial and phytotoxic properties, catechin is believed to contribute to spotted knapweed's ability to displace native plant communities. Originating in Europe, it is considered an invasive species in the Western United States and is recorded to have established populations in all fifty-six counties in Montana. Select plant species in Europe have demonstrated resistance to catechin without community displacement. It is hypothesized that the degree of resistance to catechin of neighboring plant species determines the degree of knapweed invasiveness. Using agar plates and several Montana grassland species, a bioassay was created to assess the degree of resistance of native grassland seeds to catechin. Assessed through percent germination, root length, and shoot length, the degree of resistance for each species was assessed. Identifying a Montana native grassland species with catechin resistance could provide potential means for knapweed prevention.

Follicular Development of Beef Heifers Exposed to Bulls During an Estrus Synchronization Protocol that Included a 14-D CIDR, PGF2 ALPHA and Timed Artificial Insemination (AI) and GNRH (Poster)

Luis E. Ramos, Montana State University, Bozeman
Shaun A. Tauck, Montana State University, Bozeman
Jarod R .C. Wilkinson, Montana State University, Bozeman
Jesse R. Olsen, Montana State University, Bozeman
Tiothy Gibbs, Montana State University, Bozeman

The objective was to evaluate the effect of presence of a bull on ovarian follicular development and its relationship to fertility in beef heifers using an estrus synchronization protocol that included a progesterone (P4)-containing, controlled internal drug release devices (CIDR) for 14 days, PGF 2alpha (PG, and, timed AI (TAI) and GnRH. Heifers were then assigned randomly to be exposed to bulls (BE; $n = 41$) or not exposed to bulls (NE; $n = 38$). Heifers were exposed to bulls on the day of CIDR insertion (d -32) and remained with bulls until day 3 (d 0 = day of PG injection). The heifer bull ratio was 20 to 1. CIDRs were removed 14 days (d -18) after insertion. On day 0 each heifer was injected with PG and bulls removed from BE heifers. Ovaries of each heifer were imaged ultrasonically. Heifers were observed for estrus during the next 60 h, 2x daily. Diameters of the DF at the time of CIDR removal and PG injection (d 0) did not differ between BE and NE heifers and averaged 10.3 ± 0.3 mm (mean ± SE) and 10.9 ± 0.3 mm, respectively. There was no difference in number of antral follicles between BE- and NE-treated heifers (1.7 ± 0.1 and 1.5 ± 0.1, respectively). Diameter of DF did not affect the proportion of heifers that showed estrus or time to estrus of heifers in either treatment. Diameter of DF increased ($P < 0.05$) linearly as body condition score (BSC) increased. Presence of mature bulls during an estrus synchronization protocol that included a CIDR for 14 days does not appear to influence ovarian follicular dynamics or the expression of estrus after PG in beef heifers. This may not be the mechanism whereby the presence of bulls increases fertility in the bovine. However, the relationship between DF diameter and BCS supports the concept that "more fit" females ovulate larger follicles which in turn improve fertility.

Relationship of Athletic Injuries to the Sport's Season (Poster)

Jessica Ream, University of Great Falls, Great Falls, MT
Chloe Cross, University of Great Falls, Great Falls, MT
Robert Packer, University of Great Falls, Great Falls, MT

There are many factors that contribute to a college athlete's risk for injury. Previous studies have shown that life stress can be a predictor for injury. The current study investigated if academic stress plays a role in athletic injury rate. Data collected from the university athletic trainer between 2012 and 2015 on athletic injuries was analyzed. Results indicate that season start and end dates play a role in when injuries occur. No evidence was found for academic events such as mid-terms and finals influencing the rate of injury. These findings suggest that the rate of injury for a given sport may be classified as being predominantly early-season, predominantly late-season, or predominately mid-season. Further research is needed to determine the individual factors for each sport that may explain the changes in rate of injury.

Rescuing Convergent Extension after Inhibition of an Aquaporin (Poster)

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

Much is known about how aquaporins function within individual cells. Aquaporins are membrane protein channels that are permeable to water and a subset, aquaglyceroporins, are also permeable to glycerol. Little research has been conducted on how they contribute to larger processes such as gastrulation. Gastrulation organizes cells into germ layers, which will later form different body tissues. Convergent extension cell movements are critical in driving gastrulation. During convergent extension, cells that folded into the embryo at the dorsal lip of the blastopore merge to help form the long body axis. An aquaglyceroporin, Aqp3b, is expressed during convergent extension. When it is inhibited using a morpholino oligonucleotide, convergent extension does not occur properly, which we assay using Keller tissue explants from gastrula embryos. The aquaporin aqp2 and aquaglyceroporins aqp7 and aqp9 were cloned in order to conduct rescue experiments to determine whether it is the water or glycerol permeability of Aqp3b that functions in convergent extension. I have successfully cloned the aqp7 coding region, but errors made by Taq polymerase introduced mutations into the aqp2 and aqp9 sequences. I am still working to resolve these issues. In the meantime, I have begun to determine how Aqp3b interacts with noncanonical Wnt signaling, the primary signaling pathway involved in convergent extension, utilizing the same techniques. The embryos are injected with the aqp3b morpholino oligonucleotide, as well as the mRNA for a protein involved in noncanonical Wnt signaling. If convergent extension is rescued in the explants, then Aqp3b acts though noncanonical Wnt signaling.

Inquiry, Pedagogy and Technology: Automated Textual Analysis of 30 Refereed Journal Articles (Poster)

David A. Thomas, University of Great Falls, Great Falls, MT

The storehouse of human knowledge and experience is vast, complex, messy and growing exponentially. To cope with the information explosion, scholars in many knowledge domains rely on sophisticated information technologies to search for and retrieve records and publications pertinent to their research interests. But what is a scholar to do when a search identifies hundreds of documents, any of which might be vital or irrelevant to his/her work? More and more scholars are turning to automated content analysis technologies to achieve what they do not have time to do themselves; characterize the global features of a large corpus of work and identify relationships between significant concepts and themes. This study is an informal analysis of 30 refereed journal articles identified using Google Scholar and the keyword set {inquiry, pedagogy, technology, and mathematics or science}. Mathematics (15) and science articles (15) published between 2014 and 2016 were selected, downloaded, and analyzed using Leximancer (http://info.leximancer.com/), a textual analytics tool that extracts an unbiased dictionary of terms from source documents, discovers concepts, and constructs a thesaurus of terms associated with each concept. Findings are presented using textual, tabular, and graphical formats.

Characterization of the Effects of Exogenous Camp Combined on *C. Albicans* Morphogenesis in Strains Lacking NRG1P, RFG1P, or TUP1P (Poster)

Brandon Van Tassel, Dept. of Biological & Physical Sciences, Montana State University, Billings
Kurt A. Toenjes. Dept. of Biological & Physical Sciences, Montana State University, Billings

The opportunistic human pathogen *Candida albicans* causes both superficial and lifethreatening systemic infections and is a leading cause of fungal disease in immunocompromised individuals. C. *albicans* can grow in different cell shapes, or morphologies, including yeast-like cells and a variety of filamentous forms, such as true hyphae and *pseudohyphae*. Yeast, hyphae and *pseudohyphae* have been observed at the sites of Candida infection and there is strong evidence that morphogenesis, the transition between yeast and filamentous growth forms, is essential for virulence. Many studies have implicated cAMP in the regulation of morphogenesis. cAMP acts to activate filamentation. Our lab and others have previously characterized the impact of the negative regulators, Nrg1, Rfg1, and Tup1 on the expression of HWP1, a hyphal specific gene. The goal of this project is to characterize whether the addition of exogenous cAMP will increase the expression oHWP1 in the absence of each of the negative regulators. This will help us better understand the signal transduction cascade that controls morphogenesis in C. *albicans*.

Using Nuclear Magnetic Resonance Spectroscopy to Develop Physiological Profiles for Bighorn Sheep (Poster)

Jesse R. White, Department of Animal and Range Sciences, Montana State University, Bozeman
M. Rashelle Herrygers, Department of Animal and Range Sciences, Montana State University, Bozeman
Jennifer M. Thomson, Department of Animal and Range Sciences, Montana State University, Bozeman
Valerie Copie, Department of Chemistry and Biochemistry, Montana State University, Bozeman
Brian Tripet, Department of Chemistry and Biochemistry, Montana State University, Bozeman

This study employs new techniques using nuclear magnetic resonance (NMR) to assess the relative health, physiological condition, and reproductive function of wild bighorn sheep (*Ovis canadensis*) in Montana and Wyoming. Ongoing bighorn studies in Montana and the Greater Yellowstone Ecosystem are focused on herd attributes and the population dynamics which are affected by disease, climate, habitat and physiology. Indices of herd health and physiological status are typically obtained through expensive and time consuming lab assays and field measurements. Recently, NMR spectroscopy has been used to revolutionize the assessment of human metabolic health, and we expect that there is similar potential for studies of wildlife populations. Using NMR spectroscopy to assess metabolites associated with disease, nutrition and stress may eliminate the need for many traditional assays and techniques used today. NMR can be used to evaluate a large suite of metabolites associated with a variety of physiological functions from as little as 500 uL of serum or plasma. Blood samples from 242 sheep from 13 different herds were collected during the winters of 2013-14 and 2014-15 to develop a comprehensive metabolite panel for bighorn sheep. We have used a recently developed statistical program known as MetaboAnalyst™ to begin to analyze and evaluate differences in NMR metabolic profiles among herds and across the fall-winter season when nutritional and physiological stress is expected to be acute. We will be presenting the results of this preliminary study and discussing the potential for application in wildlife management.

Sponsoring Organizations and 2016 Officers

The Montana Chapter of The American Fisheries Society

President	Leslie Nyce Montana Fish, Wildlife and Parks – Hamilton, MT
Past President	Dave Moser Montana Fish, Wildlife and Parks – Bozeman, MT
President-elect	Amber Steed Montana Fish, Wildlife and Parks – Kalispell, MT
Secretary-Treasurer	Scott Opitz Montana Fish, Wildlife and Parks – Livingston, MT

The Montana Chapter of The Wildlife Society

President	Mark Ruby U. S. Forest Service - Big Fork, MT
President-elect	Vanna Boccadori Montana Fish, Wildlife and Parks - Butte, MT
Past President	Brent Lonner Montana Fish, Wildlife and Parks - Fairfield, MT
Treasurer	Megan O'Reilly Montana Fish, Wildlife and Parks – Billings, MT
Secretary	John Waller USDI, Glacier National Park – West Glacier, MT

Montana Academy of Sciences

President	James G. Berardinelli Montana State University - Bozeman, MT
Past President	Phil Jensen Rocky Mountain College – Billings, MT
President-elect	Vacant
Executive Director	James Barron Montana State University – Billings, MT
Recording Secretary	Dan Gretch Carroll College - Helena, MT
Treasurer	Matt Queen Montana State University – Billings, MT

Design and Layout ~ **Media Works Publishing, Bozeman, Montana**
Printing ~ **Bozeman Printing Company, Bozeman, Montana**

Intermountain Journal of Sciences

Vol. 22, No. 4 - December 2016

CONTENTS

ARTICLES

Biological Sciences - Aquatic

MEETING ABSTRACTS