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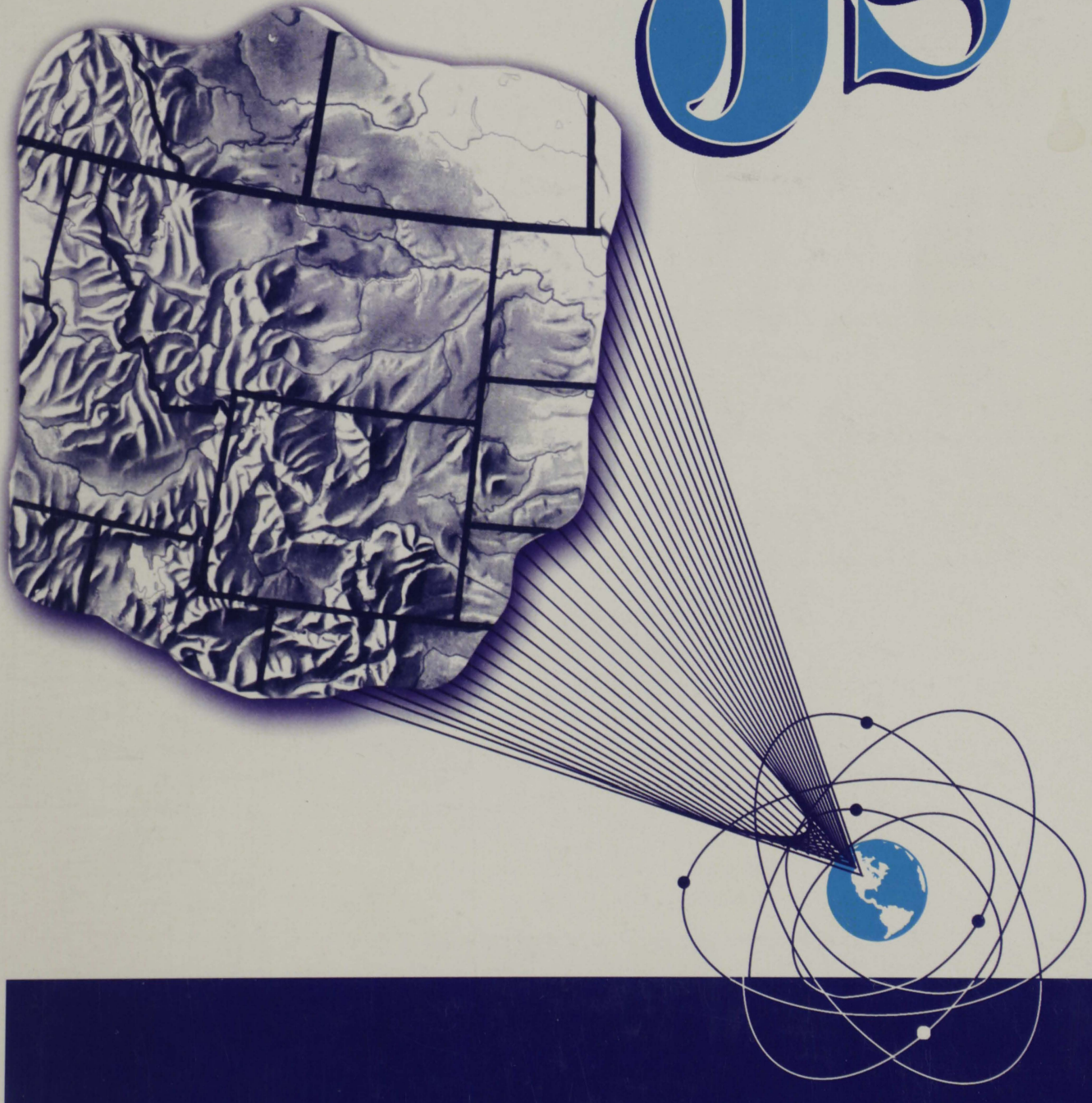

INTERMOUNTAIN JOURNAL OF SCIENCES

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

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

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

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

The organizational staff is voluntary and consists of an editorial board, an editor-in-chief, a managing editor, associate editors, a business manager and a panel of referees. The editorial board is responsible for establishing policy and the chair of the editorial board serves as liaison to the sponsoring organizations. The editor-in-chief is responsible for determining acceptability and level of revision of manuscripts based on referees' comments and recommendation of an associate editor. The managing editor serves as liaison for layout and printing. Associate editors include but are not limited to the section vice presidents of The Montana Academy of Sciences. Referees are selected on the basis of their field and specific area of knowledge and expertise.

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

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Subscriptions Total	$500.00
Page Charges	$7,310.00
Reprints	$1,440.68
Back Issue Sales	$40.00
Grant	$600.00
Total Income	**$9,290.68**
Expenses:	
Design and Printing	$7,087.01
Postage	$426.66
Office Supplies	$39.40
P. O. Box Rent	$94.00
Misc. Fees	$67.45
Reprints and Layout	$1,350.50
Website Maintenance	$273.90
Photocopy	$0.35
Total Expenses	**$9,339.27**
Balance 12/31/07	**$508.65**

Fred Nelson, Business Manager

Editorial Review Policy

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

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

Three hard copies of the submitted manuscript, with copies of the "Guidelines and checklist for IJS referees" attached are forwarded to the appropriate Associate Editor. The Associate Editor retains one 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 required for each manuscript. The two other reviewers are instructed to return the manuscript and their comments to the Associate Editor, who completes and returns to the EIC a blue "Cover Form" and all manuscripts and reviewer comments plus a recommendation for publication, with or without revisions, or rejection of the manuscript. This initial review process is limited to 30 days.

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

Acceptance

For accepted manuscripts, each copy of the manuscript containing comments thereon and other comments are returned to the corresponding author. Revised manuscripts are to be returned to the EIC in hard copy, four copies if further review is required, or one hard copy plus the computer disk if only minor revision or formatting is necessary. The revised manuscript shall be returned to the EIC within 14 days of the notification. Review of the revised manuscript by the Associate Editor and reviewers shall be completed and returned to the EIC within 14 days. An accepted manuscript will then be forwarded to the Managing Editor (ME) for final processing.

Rejection

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

Reviewer Anonymity

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

Manuscripts Submitted by Editors

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

Abstracts

Only abstracts from the annual meetings of the sponsoring organizations will be published in IJS. Other submissions of abstracts shall be considered on a case-by-case basis by the Editorial Board. Sponsoring organizations shall collect abstracts, review them for subject accuracy, key or scan them onto a 3.5" diskette, and submit the diskette and hard copy of each abstract to the EIC on or before November 1. Each abstract shall be reviewed by the EIC to assure proper grammar, compliance with IJS "Guidelines for Abstracts Only" and for assignment to the appropriate discipline section. All abstracts will be published in the December issue only.

Commentary

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

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

Literature Cited

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

Status Assessment of Burbot in Montana: Importance of a Standardized Sampling Protocol

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Abstract

Burbot (*Lota lota*) are widely distributed throughout Montana and are found in the Kootenai, Missouri, and Saskatchewan drainages within the state. However, little is known about their status. Anecdotal information from Montana Fish, Wildlife and Parks (FWP) and USDA Forest Service (USFS) fisheries biologists as well as licensed Montana anglers indicated a potential decline in burbot abundance in some populations. Surrounding states and provinces reported similar declines and even cases of near extirpation. To address concerns regarding burbot in Montana, we assessed their status by comparing statewide historic and current distributions of burbot and evaluating population characteristics, e.g., relative abundance, size structure, condition, from published and unpublished FWP andUSFS data. Burbot have been sampled using a variety of gears although most sampling effort targeted other species, i.e., rainbow and brown trout (*Oncorhynchus mykiss* and *Salmo trutta*), sauger (*Sander canadensis*), walleye (*Sander vitreus*) and sturgeon (*Scaphirhynchus* spp.) Unfortunately, status assessment of individual populations was difficult due to low sample sizes, inconsistent and non-targeted sampling efforts, and missing information, e.g , gear effort, fish lengths and weights. Undoubtedly, statewide standardized sampling protocols would facilitate a more precise assessment of Montana's burbot population. To that end, we recommend initial sampling efforts for burbot ≥ 450 mm total length use springtime hoop net sets in both lotic and lentic systems. Further, we encourage testing cod traps in lentic systems and slat traps in lotic and lentic systems to determine if these gears offer more effective sampling among a variety of sizes of burbot than hoop nets.

Key words: fishery management, burbot, conservation, *Lota lota*, Montana fishes

Introduction

Burbot (*Lota lota*) have a Holarctic distribution (McPhail and Paragamian 2000) and are the only freshwater members of an otherwise marine family (the cods, Gadidae). In North America, burbot are distributed throughout most of Canada and Alaska (McPhail and Lindsey 1970, Scott and Crossman 1973) and may be found as far south as the backwaters of the Mississippi River north of the 40th parallel (Pflieger 1997, McPhail and Paragamian 2000). Within Montana, burbot are native to the Kootenai, Missouri, and Saskatchewan drainages (Brown 1971, Penkal 1981, Holton and Johnson 2003) but have been introduced to the lower Clark Fork River [L. Katzman, Montana Fish, Wildlife, and Parks (FWP), Thompson Falls, MT, personal communication].

Although first formally described by Linnaeus in 1758 as *Gadus lota* (Nelson and Paetz 1992), this species was widely utilized worldwide before this time. Archaeological records have indicated that burbot flesh sustained the Kootenay Indians of North America during winter months both pre- and post-European settlement (McPhail and Lindsey 1970). During the 18th and 19th centuries, Europeans enjoyed burbot flesh but also recognized uses of the fish's liver oil, e.g., medicinal purposes and lamp oil (Nelson and Paetz 1992). During the Great

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Depression, burbot liver processing became economically profitable, and commercial fishing for burbot became popular in many areas of the north central United States, e.g., Lake of the Woods, Minnesota (Eddy and Surber 1943).

With the proliferation of electricity, commercial interest in burbot decreased in the United States. However, interest among anglers has varied widely over time. Many anglers have a negative perception of burbot, referring to them as "trash" or "junk" fish (Fisher 2000, Quinn 2000). Contrastingly, burbot angling has increased in popularity in isolated regions of Canada and the United States over the past 30 yrs (Quinn 2000). In Montana, angler harvest of burbot has increased in both Clark Canyon and Canyon Ferry reservoirs since the mid 1990s (B. Rich, FWP, Bozeman, MT, personal communication), and new popular winter fisheries have been established on other reservoirs, e.g., Newlan Creek Reservoir (T. Horton, FWP, Helena, MT, personal communication).

Despite rekindling interest in burbot, efforts to directly sample and understand burbot population dynamics are lacking in most provinces and states, including Montana. Fortunately, attitudes regarding burbot conservation have become more favorable due to increased angler interest and the threat of declining abundance throughout their range (McPhail 1995, Arndt and Hutchinson 2000, Taylor and McPhail 2000). A recent survey of FWP biologists and licensed Montana anglers indicated that numbers of burbot sampled or harvested have declined in several areas of the state (see Jones-Wuellner and Guy 2004) prompting concern over burbot populations throughout the state. This concern created the impetus for a statewide status assessment of Montana burbot for which the objectives were to 1) compare historic and current statewide distributions, 2) summarize available burbot population data and anecdotal information, and 3) suggest sampling protocols for both lentic and lotic populations of burbot in Montana.

Methods

Several methods were used to determine the current status of burbot in Montana. Firstly, we compared historical and current distribution data and based historical presence data on collection records published by Brown (1971). Present distribution data were based on collection records reported to the Montana Fisheries Information System (MFISH; http://nris.mt.gov/interactive.html) and collection records published by Holton and Johnson (2003). All collection records were mapped in Geographic Information Systems (GIS) layers in ArcGIS (Version 9; ESRI 2004). We calculated and compared the length (rk) of river burbot occupied historically and presently.

Secondly, we examined population data from several sources. Summary information on burbot populations was obtained from the few published fishery survey reports that contained information on burbot. In February 2003 an electronic request for burbot catch data, e.g., abundance, length, weight, was sent to FWP biologists in all seven management regions. Population characteristics, e.g., relative abundance, size structure, condition, and burbot ecology, e.g., movement, habitat use, food habits, were examined from both published and requested data. Relative abundance of burbot was indexed by catch/unit effort (CPUE). Relative abundance of fish calculated from electrofishing was summarized as number caught/pass or hr of electrofishing; abundance from trap net samples was summarized as the number caught/trap day. We used proportional size distribution (PSD; the number of fish $\geq$ 300 mm total length [TL]/number of fish $\geq$ 200 mm TL x 100; Anderson 1980, Fisher et al. 1996, Guy et al. 2007) and proportional size distribution of preferred-length fish (PSD-P; the number fish $\geq$530 mm TL/ number of fish $\geq$ 200 mm TL x 100) (Wege and Anderson 1978, Guy et al. 2007) to index size structure. Condition was assessed using relative weight (Wr; Fisher et al. 1996).

Results and Discussion

Historic and Current Status of Burbot in Montana

The burbot has a wide distribution throughout the state and is one of the few species that occurs in cold, cool, and warm water rivers. Number of collection records has increased since 1971. Brown's (1971) distribution map included 52 individual sites, and Holton and Johnson (2003) added records in the Poplar, Powder, and Bighorn rivers. The MFISH database included information on the presence of burbot at 98 locations with a potential distribution of ~ 8193 rkm (Fig. 1); this represented an 88-percent increase in distribution from Brown's (1971) data. However, this seemingly drastic expansion since 1970 was due to record deficiency prior to 1970. Further, no populations appear to have been extirpated since 1971.

Review of Published Reports and Solicited Burbot Data

Although we found few published reports that included burbot population data, reports that we located, as well as data provided by FWP biologists, yielded information from 19 water bodies. Biologists that sent us unpublished data were personally contacted to verify conclusions we made from our analysis. Most (79%) of this information came from lotic habitats. Seven areas within the Missouri River and six areas within the Yellowstone River were sampled. Burbot collected in lentic habitats were mostly from reservoir systems.

Kootenai River.—A relatively productive burbot fishery existed in the Montana section of the river before the completion of Libby Dam, an Avista Corp. facility built for hydroelectric power and flood control in 1972 (Hammond and Anders 2003). Subsequently, angler catch rates of

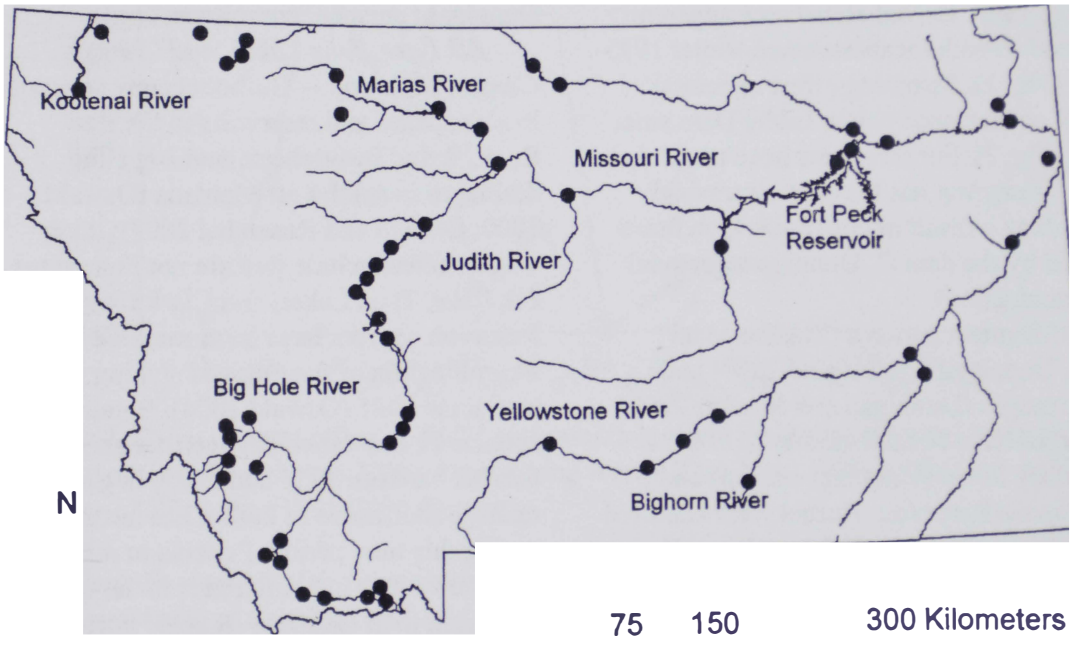

Figure 1. Comparison of historic (Brown 1971) and present burbot distributions [Holton and Johnson 2003; Montana Fisheries Information System (MFISH; http://nris.mt.gov/interactive.html)]. Brown's (1971) distribution is represented by dark circles. Potential distribution provided by Holton and Johnson (2003) and the MFISH database is represented by dark solid lines. Present distributions (8193 rkm) assumed burbot were found in the area between two locations within the same river. Geographically important areas are labeled.

several species have declined over the past two decades, which prompted monitoring of the Kootenai River and Lake Koocanusa fish communities (J. Dunnigan, FWP, Libby, MT, personal communication). Paragamian (2000) attributed declines of most fishes, including burbot, to the operation of Libby Dam that has considerably altered seasonal discharges, particularly during winter months. Winter discharges are presently three to four times greater than pre-construction winter discharges (Paragamian et al. 2000).

Following construction of the reservoir, the burbot population in Lake Koocanusa remained relatively stable (Chisholm and Fraley 1986). However, recent sampling efforts have indicated reduced numbers of burbot in the river downstream of Libby Dam. Burbot have been collected using trap nets in the river below Libby Dam during the winter months, i.e., Dec through Apr from 1991 to 1992 and Dec and Feb from 1993 to 2003, and below Kootenai Falls (50 rkm downstream of Libby Dam) from 1991 to 1999. Burbot abundance apparently declined in both locations since winter 1995-1996 (Fig. 2). Sampling effort remained steady or increased below Libby Dam since 1991 (Fig. 2), but biologists have noted that burbot sampling has become increasingly difficult as a result of consistent high flows created by the dam (J. Dunnigan, personal communication).

Movement patterns (Snelson et al. 2000, Dunnigan and Sinclair 2008) and home ranges (Dunnigan and Sinclair 2008) of burbot have been documented in the Kootenay River (Canadian section) and Koocanusa Reservoir. Burbot were captured using hoop nets in the Tobacco River Bay near Rexford, Montana, in 1995 and 1997 (Snelson et al. 2000); five burbot were implanted with radio tags in 1995, and 11 were implanted with ultrasonic tags between 1995 and 1997. Most burbot moved only short distances and displayed site fidelity within Tobacco River Bay (Snelson et al. 2000). However, two burbot moved from the reservoir to the river and were located near Wardner, B.C. (74 rkm) during spring 1996.

More recently, Dunnigan and Sinclair (2008) captured and implanted acoustic and combined radio/acoustic tags in adult burbot from Koocanusa Reservoir. They tracked burbot weekly during two spawning seasons and an interim period. Home ranges of burbot were several orders of magnitude larger than those reported for other fishes; this may be attributed to the pelagic nature of some prey species sought by burbot in Koocanusa Reservoir rather than spawning behavior (Dunnigan and Sinclair 2008). They detected no discernable patterns in seasonal movement, and most burbot demonstrated high fidelity to the side of the reservoir where originally captured. These results likely indicated that burbot do not migrate to the river to spawn and likely reproduce within Koocanusa Reservoir. Although results of this study appear to contradict those of Snelson et al. (2000), :findings of Dunnigan and Sinclair (2008) are likely stronger due to increased sample size and tracking frequency and more thorough coverage of Koocanusa Reservoir (J. Dunnigan, personal communication).

Elk Lake, Twin Lakes, and Clark Canyon Reservoir.-Burbot occupy several lowland lakes and reservoirs in the Red Rock, Ruby, Beaverhead, and Big Hole drainages in southwest Montana (Oswald 2000, Oswald and Rosenthal 2007); these water bodies include (but are not limited to) Elk Lake, Twin Lakes, and Clark Canyon Reservoir. Burbot have been sampled using a combination of floating and sinking gill nets since 1991 (Oswald 2004). Relative abundance has varied between six and 23 fish/net between 1991 and 2003. In general, relative abundance of burbot has increased during this time period. Patterns in relative abundance may explain trends in the range and mean total length of sampled burbot (Oswald 2004). For example, when relative abundance was high, mean length declined, and the range of total lengths decreased from years of lower relative abundance; this indicated potential affects of intraspecific competition (Oswald 2004). Growth rates were slow and ultimate size for burbot was limited compared to other populations; these

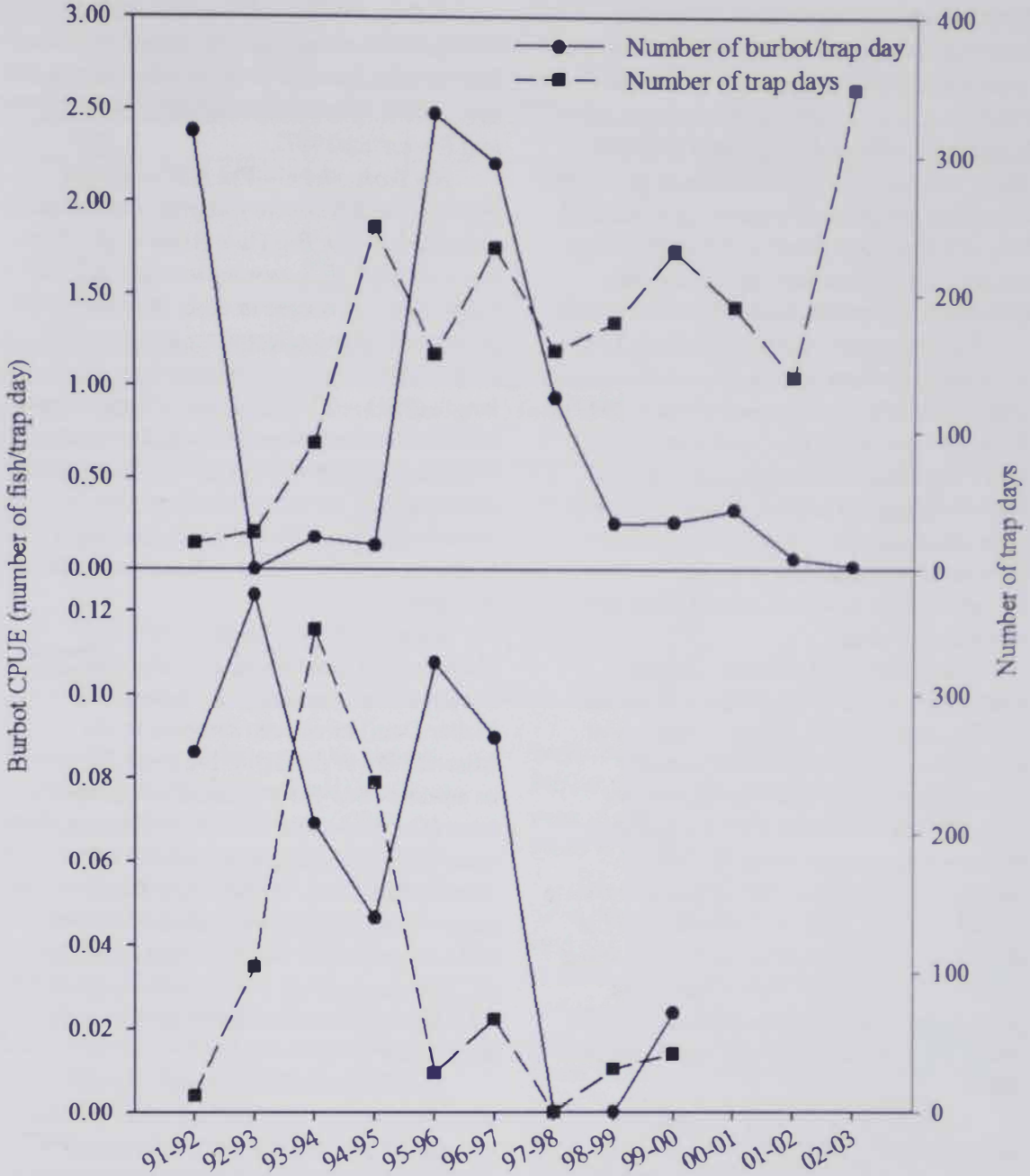

Figure 2. Catch per unit effort (CPUE) and sampling effort for burbot captured by trap nets in the Kootenai River below Libby Dam during winter (Dec-Mar) 1991-2003 (Top) and below Kootenai Falls during 1991-2000 (Bottom).

smaller lengths coupled with the greater relative popularity of abundant Yellowstone and westslope cutthroat trout (*O. clarkii bouvieri* and *O. clarkii lewisi*) may limit the value of burbot in the Elk Lake recreational fishery (Oswald 2004). Burbot sampling with sinking gill nets in Twin Lakes occurred sporadically since 1964 (Oswald 2004). Relative abundance varied from < one fish/net in 1992 to four/net in 1970. In 1998, Oswald and Roberts (1998) reported that burbot composed ~ 23 percent of the total catch by number. However, burbot "dominated" the total catch by number a few years later (Oswald 2004); a change in sampling timing from summer (1998) to autumn (2004) likely explained this pattern.

In 2003 and 2004, modified fyke nets were used in Twin Lakes to minimize mortality of captured fish (Oswald 2004).

Most effort was targeted near observed burbot spawning areas but some burbot were captured in other seasons and locations. Fyke net sampling appeared to sample older, larger fish compared to gill nets (Oswald 2004). Captured burbot were given pelvic fin clips, and subsequent resampling of marked fish indicated high fidelity of burbot to trap net location, particularly to the narrows between the two lake basins (Oswald 2004).

Current sampling efforts in Twin Lakes have employed baited cod traps immediately after ice-off (Hochhalter and Oswald 2007). Relative abundance from cod traps in 2007 was 10 fish/trap. Cod traps and fyke nets have been used to capture and mark burbot with numbered Floy tags in recent efforts to determine abundance (Hochhalter and Oswald 2007); however, results from this study are pending.

Clark Canyon Reservoir supports a relatively popular burbot fishery (Oswald and Rosenthal 2007). Prior to 2006, most information on burbot in this reservoir was obtained from winter creel surveys (Oswald and Rosenthal 2007). Creel data indicated that burbot in Clark Canyon Reservoir were among the largest in the state (Oswald 2002). However, several years of drought appear to have reduced the number and average length of burbot harvested, potentially explaining a reduction in angler use of the reservoir (Oswald and Rosenthal 2007).

Creel surveys have continued, but recent sampling efforts have used baited cod trap sets and modified fyke nets in observed spawning locations in both spring and autumn (Hochhalter and Oswald 2007). Most (90%) burbot were captured using fyke nets at active spawning sites after ice-off (Oswald and Rosenthal 2007). All burbot captured, regardless of gear or season, were given Floy tags in an effort to estimate the population based on mark-recapture data. Oswald and Rosenthal (2007) reported a population estimate of 52,021 ± 22,976. However, autumn sampling did appear to proportionately sample older, larger individuals compared to spring sampling. Thus, population size may have been underestimated (Oswald and Rosenthal 2007). More recaptures are needed to increase the number of recapture events and precision of population estimates (Oswald and Rosenthal 2007).

Big Hole River.—The USDA Forest Service and FWP have sampled most of the tributaries of the Big Hole River in an effort to inventory fish communities. In 2002, 149 burbot were collected in eight streams. Total length of burbot collected varied from 190 to 332 mm; most were smaller than stock length (PSD = 23; PSD-P = 0). Small sizes of burbot collected in these areas suggested that low-order streams in the Big Hole River drainage provide nursery habitat. Better understanding of life history dynamics of burbot in this watershed will require further research.

Missouri River Upstream of Great Falls.—Four river reaches (Craig, Cascade, Hardy, and immediately downstream of Holter Dam) have been sampled in the Missouri River during spring (Mar-Jun) or autumn (Sep-Nov) to monitor rainbow trout (*Oncorhynchus mykiss*) and brown trout (*Salmo trutta*) populations (FWP, unpublished data). Burbot are difficult to catch during electrofishing as they tend to roll along the river bottom when stunned (T. Horton, personal communication), but all burbot captured are measured for total length and weight.

The Holter Dam and Hardy reaches have been sampled in the past three decades, and most sampling occurred in autumn (Tables 1 and 2). Most fish sampled within the Holter Dam reach were < 530 mm and condition values across all size categories were low (Table 1). Electrofishing effort in this area showed sporadic relative abundance over time (Table 1). However, more recent hoop net sampling efforts in this area showed higher catch rates than in areas further downstream (Horton and Strainer 2008).

Fish captured in the Hardy reach may be in poorer condition than in the Holter Dam section (Table 2), but the total length of fish sampled has varied from 150 to 730 mm. Relative abundance as

Table 1. Catch/unit effort and mean relative weight (Wr) values of burbot incidentally captured by electrofishing in the middle Missouri River immediately downstream of Holter Dam during spring (Mar-Jun) and autumn (Sep- ov) from 1983 to 1993. umbers in parentheses indicate the 95-percent confidence interval.

Year	Season	Number per pass	Mean Wr
1983	Autumn	0.67	76 (7)
1986	Spring	0.80	77 (5)
1986	Autumn	8.50	71 (10)
1987	Autumn	8.00	76 (5)
1993	Autumn	3.00	84 (7)

Table 2. Catch /unit effort and mean relative weight (Wr) values of burbot incidentally captured by electrofishing in the middle Missouri River near the town of Hardy, Montana, during pring (Mar-Jun) and autumn (Sep- ov) from 1981 to 2000. umbers in parenthese indicate the 95-percent confidence interval.

Year	Season	Number per pass	Mean Wr
1981	Autumn	0.50	69 (4)
1992	Autumn	11.00	82 (3)
1993	Spring	1.33	68 (2)
1993	Autumn	13.00	79 (2)
1994	Spring	11.00	71 (2)
1999	Autumn	21.75	69 (3)
2000	Autumn	27.25	67 (4)

indexed by electrofishing may be higher in the Hardy reach than in the Holter Dam reach, particularly in 1999 and 2000. However, these results may be eschewed due to university research and subsequent additional sampling effort in this area during those years (T. Horton, personal communication).

The Craig and Cascade reaches have been sampled twice/yr (spring and autumn) since 1983. Burbot have been collected nearly every spring and autumn from 1983 to 2002 near Cascade and Craig (Fig. 3). Relative abundance appeared to increase over time. However, this trend was likely due to increased interest from and adeptness of field crew in capturing burbot since 1996 (T. Horton, personal communication). Thus, only trends in burbot relative abundance were analyzed from 1996 to 2002. The relative abundance of burbot in both reaches appeared higher during autumn than spring. Several burbot sampled in this stretch were near trophy length (820 mm; Fig. 4) and may provide a unique angling opportunity. Maximum lengths of burbot sampled in these two reaches were similar, but burbot sampled in the Craig reach were generally larger those in the ascade reach (Fig. 4). Burbot of all ize classes in both reaches were in generally poor condition (pooled mean Wr = 78 ± 1).

Biologist working on the Missouri River near Great Falls, Montana, have been studying various aspects of burbot ecology In 2006, a 2-yr spring population assessment and movement study was completed between Holter Dam and Broadway Bay in Great Falls (152 rkm) using hoop nets, cod traps, and slat traps (Horton and Strainer 2008). Results from this study indicated a higher abundance of burbot near Holter Dam than in sections further downstream (Horton and Strainer 2008). Thi result was somewhat surprising as velocity near the dam may be higher than in other sections, and burbot can often not sustain swimming action in water velocities > 25 cm/s for >10 min (Jones et al. 1974). Thus, increased flows downstream of dam often impair fitness of burbot (Paragamian 1993, Paragamian 2000, Kozfkay and Paragamian 2002). However, decrease in downstream water temperature regimes since the construction of reservoirs in the upper Missouri River, i.e., Canyon Ferry, Hauser,

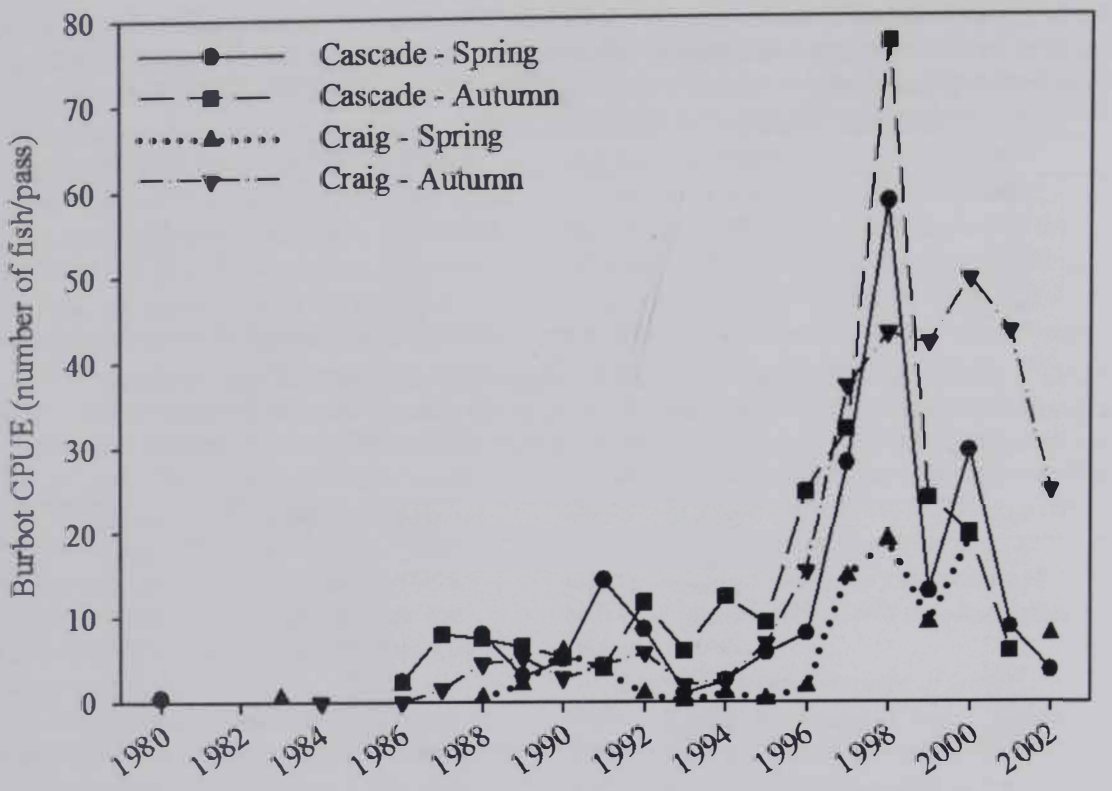

Figure 3. Number of burbot incidentally collected per pass during electrofishing surveys in the mainstem of the Missouri River near the towns of Cascade and Craig during spring (Mar-Jun) and autumn (Sep-Nov) from 1980 to 2002.

and Holter, may have had a positive effect on burbot abundance (Horton and Strainer 2008).

All burbot captured in the upper Missouri River during spring 2005 and 2006 (n = 303) were tagged with Floy and passive integrated transponder tags (Horton and Strainer 2008). Twenty-six tagged fish were recaptured during sampling or were returned by anglers. Most of the burbot were recovered within 10 rkm of their original tagging location; three burbot moved >30 rkm and all moved downstream (Horton and Strainer 2008). To date, there is no information on daily or seasonal movements or behaviors of burbot in the upper Missouri River.

Missouri River, Great Falls to Fort Peck Dam.—Burbot were perceived as relatively uncommon in the Missouri River between Great Falls and the Fred Robinson Bridge (B. Gardner, FWP, Lewistown, MT, personal communication). Electrofishing provided limited data on relative abundance of burbot in this section of the Missouri River from 1999 to 2000 (Tables 3 and 4). Many of the burbot captured in this area were larger than quality length (380 mm).

Burbot were often incidentally captured during sturgeon (*Scaphirhynchus* spp.) netting and trawling in the Missouri River mainstem between Fred Robinson Bridge and the headwaters of Fort Peck Reservoir. Pallid sturgeon (*S. albus*) sampling from 1994 to 2002 yielded low numbers of burbot of lengths varying from 100 to 1100 mm. Trawling for age-0 sturgeon in the delta area of Fort Peck Reservoir (RKM 3056) occasionally yields a few age-0 burbot (B. Gardner, personal communication).

Efforts to sample pallid sturgeon in the Marias and Judith rivers following similar protocols to those for the Missouri River have also sampled burbot, but not in great numbers (Anne Tews, FWP, Lewistown, MT, personal communication). Adult burbot in these rivers were typically large, and length of burbot sampled in the Marias River varied from 300 to 650 mm. Only four burbot were collected from the Judith River in 2002.

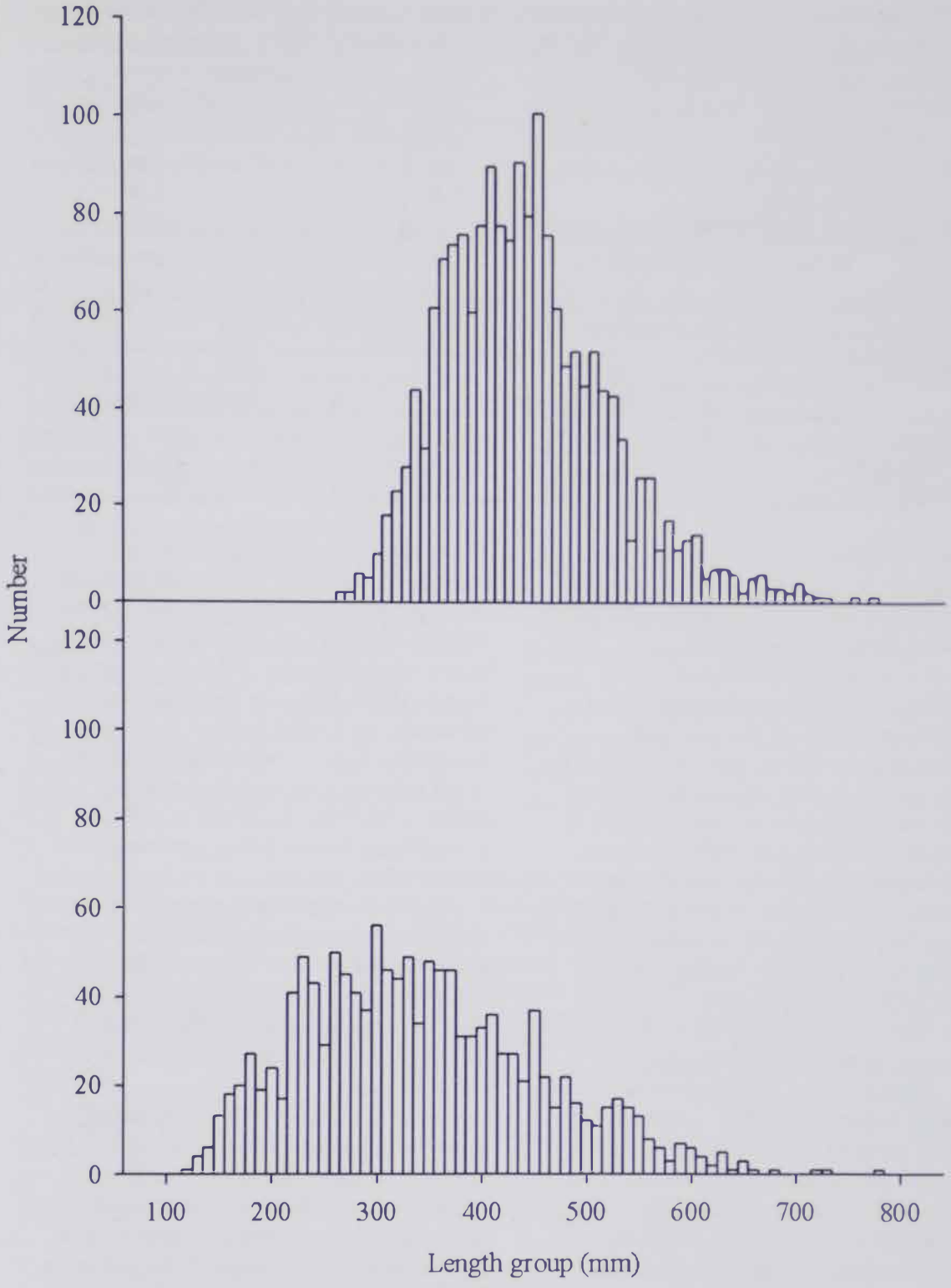

Figure 4. Size structure of burbot incidentally collected during electrofishing surveys in the mainstem of the Missouri River near the towns of Craig (Top; n = 1748) and Cascade (Bottom; n = 1304) during spring (Mar-Jun) and autumn (Sep-Nov) from 1980 to 2002 (n = 3055)

Creel surveys for the Missouri River between the Fred Robinson Bridge and Peggy's Bottom (distance = 35 rkm) indicated little fishing pressure on burbot. In a 2002 creel survey, it was reported that burbot were fished during only two angler days from April through June (Gilge and Perszyk 2002). During these two days,

Table 3. Catch/unit effort of burbot incidentally captured by electrofishing in the Missouri River by station during standardized fisheries surveys in 1999 and 2000.

Location	Number/hr	
	1999	2000
Coal Banks	0.60	0.10
Grand Island	0.90	0.30
Judith Landing	0.30	0.20
Marias River Confluence	0.00	0.20

Table 4. Number and mean total length (mm) of burbot incidentally sampled in the Missouri River by station during standardized electrofishing surveys in 1999 and 2000.

Station	1999		2000	
	n	Mean total length	n	Mean total length
Loma	3	307	4	424
White Rocks	1	406	2	368
Stafford Ferry	23	447	1	742

35 burbot were caught and 28 were kept. Daily harvest and possession limits in this area are presently five fish per day (Montana Fish, Wildlife and Parks 2008).

In contrast to the river, a relatively popular winter fishery exists within Fort Peck Reservoir. However, creel data is lacking and few burbot were sampled in the reservoir due to time constraints resulting from walleye (*Sander vitreus*) sampling in the spring (M. Ruggles, FWP, Fort Peck, MT, personal communication). Anglers have reported catching a variety of sizes suggesting that several year classes were present in the reservoir. Nevertheless, there has been some concern that burbot abundance is declining in the reservoir (M. Ruggles, personal communication).

Missouri River, Fort Peck Dam to North Dakota Border.— Gardner and Stewart (1987) sampled the lower mainstem of the Missouri River and its major tributaries in the late 1970s to early 1980s. They collected 533 burbot during that time. Mean back-calculated lengths at age indicated that burbot grew fastest between ages 5 and 6, coinciding with a shift from insectivory to piscivory. Burbot in this section of the Missouri River grew more slowly at younger ages but more rapidly at older ages compared to other North American populations (Gardner and Stewart 1987). Burbot in this section of the Missouri River did not migrate great distances. In fact, tagging and recapture information revealed only 9 percent of recaptured burbot moved >16 rkm from their original capture site; the largest movement was 19 rkm (Gardner and Stewart 1987). However, these fish were not monitored for diel or other short-term movements. Little information is available on the spawning habits of burbot in the section of Missouri River due to difficulty in monitoring burbot during spawning (Feb; Brown 1971).

Few burbot have been sampled in the Milk River suggesting the species was not abundant (K. Gilge, FWP, Havre, MT, personal communication). Anecdotal observations suggested that the species is associated with tailwaters and riprap of diversion dams.

Yellowstone River.—Burbot have been incidentally sampled in both spring and autumn throughout the Yellowstone River basin. In the upper reach (above and including the Bighorn River) burbot have been sampled in the Bighorn River, Bighorn Lake, and in the mainstem at several locations from Big Timber to Huntley Dam. Unfortunately, burbot were not easily sampled and were rarely targeted (M. Vaughn, FWP, Billings, MT, personal communication). Standardized sampling for other species such as sauger (*S. canadense*) and walleye generally occurs in spring and autumn throughout the upper

reach; burbot were more often incidentally collected in the spring. Larger burbot were more common in the Yellowstone River than Bighorn Lake or Bighorn River (Table 5). Condition of burbot in the upper drainage is generally low with no Wr values > 95 (Table 5).

Annual standardized fish community sampling using several gear has occurred at five stations in the lower Yellowstone River (below the Bighorn River) since 1984 (Table 6). Most burbot were sampled by electrofishing; however, a few were sampled by drifting trammel nets, and one was sampled in a trap net. Effort information is not available; thus, calculations of PUE were not possible.

Burbot captured in the lower Yellowstone River generally do not exceed preferred length (530 mm; Table 7). Penkal (1981) suggested that rearing of juvenile burbot may occur downstream from Forsyth diversion. However, larger fish might possibly move out of the system, experience higher mortality, or were not sampled. Angling most likely had no effect on size structure of the population because harvest of burbot from the Yellowstone River was minimal (V. Riggs, FWP, Miles City, MT, personal communication). Condition value for burbot in the lower Yellowstone River vary between 63 and 155; condition did not appear to differ by length category (Fig. 5).

Management Implications

Broad-scale comparisons of burbot population characteristics and distribution were difficult due to lack of standardized and targeted sampling. Nevertheless, we are confident that burbot have not been extirpated from historical locations described by Brown (1971). However, contemporary concern that burbot abundance has declined in many waters throughout Montana could not be ascertained in this study. Our recommendation is to develop a statewide standardized sampling program for burbot to achieve a better understanding of their status.

In developing a sampling program for any species, life history, efficiency of sampling gear, capture probability, size selectivity, time of year, and other logistical

Table 5. Number, size structure, and relative weight (Wr) of burbot sampled during annual sauger (*Sander canadensis*) and walleye (*S. vitreus*) surveys in the upper Yellowstone River (above and including the Bighorn River) from 1986 to 2001. Size structure is indexed by proportional size distribution (PSD) and proportional size distribution of preferred length fish (PSD-P). Mean Wr is reported by incremental length category [stock to quality (S-Q; 200-379 mm), quality to preferred (Q-P; 380-529 mm), preferred to memorable (P-M; 530-669 mm), memorable to trophy (M-T; 670-819 mm), and trophy (T; > 820 mm)].

					Wr				
Location	**Year**	**n**	**PSD**	**PSD-P**	**S-Q**	**Q-P**	**P-M**	**M-T**	**T**
Bighorn Lake	1997	18	89	22	75	74	83		
	1998	1	0		95				
	1999	3	33		62				
	2000	7	43	14	70	60			
	2001	4	75		68	90			
Bighorn River	1986	1	100	100			85		
	1989	2	100	100			79	78	
	1990	1	0		72				
	1991	5	60	20	71	82	76		
	1996	8	63		75	82			
	1999	2	100			79			
	2000	10	100	40		84	66	73	
Yellowstone River	1989	85	100	86		75	72	74	63
	1995	38	89	50			86	86	80
	1999	10	100	60		74			
	2000	96	95	57	77	70	71	72	

Table 6. Number of burbot sampled during standardized fisheries surveys in the lower Yellowstone River (below the Bighorn River) by location and season [spring (March-June) and autumn (Sep-Nov)] from 1984 to 2002.

	Intake		Fallon		Miles City		Forsyth		Rancher Ditch	
Year	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
1984										
1985										
1986								4	2	9
1987							5			
1988							13	3		
1989										
1990						14				
1991	2									
1992				1		2		7		
1993				1		1		2		
1994		5		2		7		2		
1995		15		3		2		6		
1996		1		2		1	6	4		
1997						1	1	1		
1998		4								
1999	50									
2000										
2001	1									
2002	4					1		1		
Totals	**58**	**27**	**0**	**13**	**1**	**29**	**25**	**31**	**2**	**9**

Table 7. Size structure of burbot sampled during standardized fisheries surveys in the lower Yellowstone River drainage (below the Bighorn River) from 1986 to 2001. Size structure is indexed by proportional size distribution (PSD) and proportional size distribution of preferred length or longer fish (PSD-P).

Year	n	PSD	PSD-P
1985	1	0	0
1986	5	80	40
1987	5	20	20
1988	7	14	14
1989	0	0	0
1990	8	50	13
1991	1	0	0
1992	11	18	0
1993	4	25	0
1994	14	57	21
1995	20	40	10
1996	15	20	13
1997	3	100	67
1998	3	33	33
1999	43	30	14
2000	2	50	0
2001	2	0	0
2002	6	17	0

matters must be considered. Burbot typically occupy the hypolimnion of oligotrophic and mesotrophic lakes (Ryder and Pesendorf 1992), where they tend to be associated with bedrock or rubble substrates (Edsall et al. 1993). Lotic habitat preferences are less understood, but it is believed that burbot in the southwest portion of their range, i.e., Idaho, Montana, and Wyoming, may be restricted to backwater areas of cooler

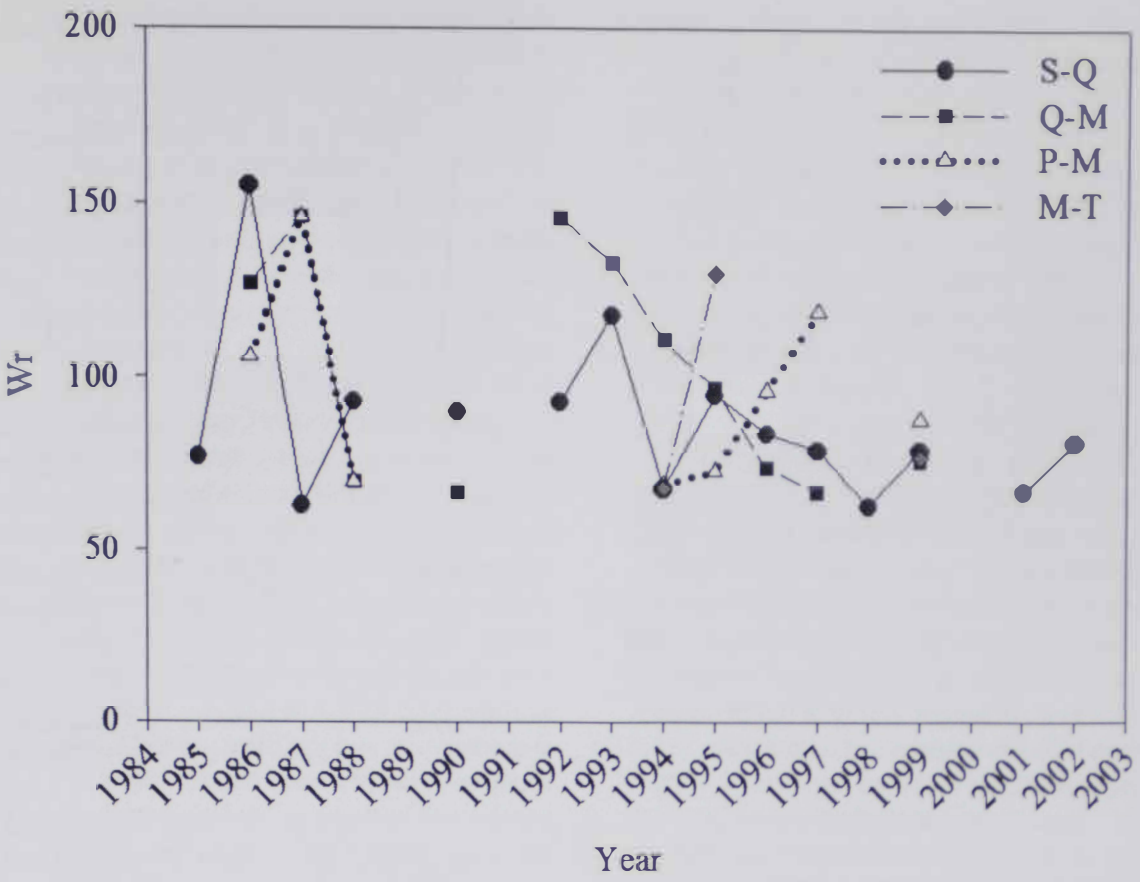

Figure 5. Mean relative weight (Wr) by size category of burbot captured in the lower Yellowstone River (below the Bighorn River) from 1985 to 2002. Length categories are: stock to quality (S-Q; 200-379 mm), quality to preferred (Q-P; 380-529 mm), preferred to memorable (P-M; 530-669 mm), and memorable to trophy (M-T; 670-819 mm).

high-altitude systems (McPhail and Paragamian 2000). Hoop nets are arguably the most effective gear for sampling larger (≥ 450 mm TL) burbot in both lentic and lotic habitats (Lawler 1963, Bernard et al. 1991). Baiting gears with an odiferous prey species such as kokanee (*O. nerka*) has shown to increase sampling efficiency as burbot use olfactory senses to locate prey (Bernard et al. 1991).

An experimental gear has been tested in Duncan River and Kootenay Lake in British Columbia and in Twin Lakes and Clark Canyon Reservoir in Montana that may improve sampling efficiency in lentic ecosystems (Spence 2000; Hochhalter and Oswald 2007). This gear is based on the design of commercial traps used in British Columbia's coastal black cod (*Anoplopoma fimbria*) fishery. Cod traps baited with kokanee were effective in capturing burbot in Kootenay Lake and Spence (2000) found to them easier to transport and store than hoop nets. Spence (2000) also suggested that cod traps were more effective than hoop nets especially during longer sets (>7 days). Hochhalter and Oswald (2007) have documented success sampling with cod traps in Twin Lakes and Clark Canyon Reservoir, particularly in known burbot spawning locations. Based on these results, we recommend continued testing of cod traps in other Montana lentic systems.

Results from Spence (2000) and Hochhalter and Oswald (2007) for sampling burbot in lentic environments differ from those of Horton and Strainer (2008) for sampling in the Missouri River of Montana. Horton and Strainer (2008) found hoop nets were more effective than cod traps in sampling burbot on a 152-km stretch of the Missouri River in March

2005 and 2006. Habitat type may explain these differences. Another reason for this disparity may be related to the fishing duration of the gear. Horton and Strainer (2008) allowed hoop nets and cod traps to soak for approximately 2 days. However, Spence (2000) allowed traps to fish for up to 7 days. Further, positioning of the bait within the gears may affect their efficiency [see Horton and Strainer (2008) for further discussion]. Based on information from Spence (2000), Hochhalter and Oswald (2007), and Horton and Strainer (2008), we recommend the initial use of hoop nets in the standardized protocol for larger fish (≥ 450 mm TL) because use of cod traps has not been thoroughly tested in Montana and because comparisons between lotic and lentic ecosystems is sometimes necessary. However, if comparability is not necessary, then biologists may want to consider experimenting with cod traps.

Gear recommendations listed thus far are largely targeted at sampling burbot ≥450 mm TL. Bernard et al. (1991) found that burbot smaller than this length were not fully recruited to hoop nets. Horton and Strainer (2008) reported that slat traps were more effective at sampling burbot ≤ 300 mm TL than hoop nets or cod traps in the upper Missouri River. To our knowledge, no such size selectivity comparison has been completed for these three gears in lentic systems. Relative abundance and size distribution information of small fishes is important as they may provide information on year-class strength and ontogenous habitat use (Horton and Strainer 2008). We recommend that slat traps be tested in lentic and other lotic waters to determine if this gear is appropriate for sampling smaller burbot and to determine whether catches of smaller fish are comparable between these different waterbody types.

Seasonal considerations were equally as important as choice of gear in developing a standardized sampling regime. Burbot are nocturnal fish that spawn in the winter months under ice (Dec–early Mar, Brown 1971, Scott and Crossman 1973) and are most active at this time; however, winter sampling during adverse ice conditions is difficult. Summer sampling yields far fewer burbot per effort due to their relative inactivity (Bernard et al. 1993). Bernard et al. (1993) found that sampling precision is maximized in small and moderate-sized lakes if sampling is done immediately after the lake becomes ice-free in the spring or just before it freezes over in the late autumn or early winter. During the autumn months as the daylight period shortens and water temperatures cool, burbot were equally likely to be active during the day and night (Kroneld 1975). Further, burbot may be moving to staging areas for their winter spawning activities (Kroneld 1975). Thus, autumn may be the ideal season to sample burbot. This observation is supported in Montana by the data we received from southwestern Montana lowland lakes and reservoirs and the Cascade and Craig sections of the Missouri River, where numbers of burbot captured apparently are consistently higher during the autumn months. However, fisheries biologists already experience time constraints during this season while surveying other recreationally important species; therefore, we recommend spring (as close to ice-out as possible) sampling initially with plans to compare autumn and spring sampling efficiencies at a later date.

Studies are currently being conducted in other areas of the burbot's range in North America, particularly in the western U.S. and Canada, to determine habitat use, verify the status of remaining stocks, and assess the impact of dam operations on burbot recruitment (Spence 2000). A standardized sampling protocol in Montana will help fill this paucity of information on burbot life history and population characteristics in the southwest portion of their North American range. Despite the widespread distribution of burbot in Montana, we know little about this native and potentially important recreational species. The state of Montana has a unique opportunity to implement a proactive approach to burbot conservation, which may aid in the management of this species throughout its range.

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Merriam's Turkey Poult Survival in the Black Hills, South Dakota

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Abstract

We investigated poult survival from hatching to 4 wks of age for Merriam's wild turkey (*Meleagris gallopavo merriami*) poults in the southern Black Hills, South Dakota. We estimated survival from 841 poults reared by 57 radio-marked wild turkeys (n = 52 adult females, n = 5 yearling females). Survival of poults to 4 wks posthatch averaged 33 percent with 54 percent of the mortality occurring in the first 7 days after hatching. Merriam's turkey poult survival in the southern Black Hills was low compared to Merriam's populations found elsewhere in the entire current range. Survival of poults increased with age, fewer precipitation events, and fewer extreme cold and wet events. The interaction of age of poults with cold and wet events through 15 days posthatch indicated that younger poults were more susceptible to cold and wet weather events than older-aged poults. We observed several poults ≤ 3 days of age that apparently died from hypothermia. A fine-scale based weather index that uses individual weather stations for specific areas occupied by turkeys may be a valuable tool for managers to estimate production in Merriam's turkeys if survey or radio telemetry data are not available.

Key words: Black Hills, Merriam's turkey, *Meleagris gallopavo merriami*, ponderosa pine, poult, precipitation, survival, wild turkey

Introduction

The native range of Merriam's turkeys (*Meleagris gallopavo merriami*) was from northern Colorado, south into Arizona, New Mexico, Oklahoma, and possibly western Texas concurrent with distribution of ponderosa pine (*Pinus ponderosa*) (Ligon 1946, Schorger 1966). The range of Merriam's turkeys has since expanded, and South Dakota Department of Game, Fish and Parks (SDGFP) introduced wild-trapped Merriam's turkeys from Colorado and New Mexico into the southern Black Hills near the towns of Custer and Hot Springs in 1950 and 1951 (Peterson and Richardson 1975). Merriam's turkey populations have fluctuated throughout their entire range historically and predation, human exploitation, and decrease in habitat quality through poor timber and range management practices may have lead to some population declines (Ligon 1946).

Survival of wild turkey poults is a key parameter influencing annual population fluctuations (Kurzejeski and Vangilder 1992). Limited knowledge of factors affecting survival during this critical life stage makes evaluating annual population fluctuations difficult (Hubbard et al. 1999). Survival of Merriam's turkey poults can vary considerably from 36–59 percent (Wakeling 1991) with most poult mortality occurring before poults reach an age of 2 wks (Glidden and Austin 1975, Lehman et al. 2001, Spears et al. 2007). Survival of eastern turkey (*M. g. silvestris*) poults is reduced by low temperatures and precipitation (Roberts and Porter 1998a). Information on factors influencing survival of Merriam's turkey

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poults is lacking both in its indigenous (Scott and Boeker 1975, Wakeling 1991) and introduced ranges (Crawford and Lutz 1984, Hengel 1990, Flake and Day 1996, Rumble et al. 2003). No studies have correlated weather variables with poult survival within the Merriam's turkey range. Our objectives were to estimate poult survival rates and evaluate the relationship between weather indices and survival of Merriam's turkey poults near the northeastern extension of their expanded range. Understanding natural variation of vital rates for Merriam's turkeys and how climate conditions may affect those vital rates is useful for resource managers (Rumble et al. 2003).

Study Area

Our study area (1213 km^2) was located in Custer and Fall River counties in the Nouthern portion of the Black Hills physiographic region (Johnson et al. 1995). Elevations in the southern Black Hills range from 930 to 1627 m above mean sea level with a varied topography of rocky ridges, drainages, canyon walls, and mountain valley (Kalvels 1982). The study area has a continental climate with mean annual precipitation of 44.2 cm and mean annual temperature of 7.8 ºC (National Climatic Data Center 1971–2000). Land cover types were mostly ponderosa pine forest (48 %) and meadows (23 %). Twenty-nine percent of the study area was burned by wildfires in 2000 and 2001. Rocky Mountain juniper (*Juniperus scopulorum*) and deciduou draws comprised < 1 percent of the study area. Western snowberry (*Symphoricarpos occidentalis*) and common juniper (*Juniperus communis*) were the most common shrubs beneath the forest canopy, whereas serviceberry (*Amelanchier alnifolia*), bearberry (*Arctostaphylos uva-ursi*), and chokecherry (*Prunus virginiana*) occurred less frequently (Hoffman and Alexander 1987). Common grasses included needle-and-thread (*Stipa comata*), western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), little bluestem (*Schizachyrium scoparium*), and prairie dropseed (*Sporobolus heterolepis*) (Larson and Johnson 1999).

Method

Capture and Radio Telemetry

We captured female Merriam's turkey in winter from 2001 to 2003 using cannon net (Dill and Thorn bell) 1950, Austin et al. 1972), rocket net (Thompson and Delong 1967, Hawkns et al. 1968, Wunz 1984), and drop nets (Glazener et al 1964). We recorded age of captured female as either adult (≥ yr old) or yearling (< 1 yr old) based on presence or absence of barring on the ninth and tenth primary feather (Williams 1961). We fitted females with 98-g backpack mounted radio transmitters equipped with activity, loafing, and mortality signals (Advanced Telemetry Systems, Isanti, MN, USA). We obtained locations of female turkeys systematically throughout nest irnt1at1on and incubation to identify nesting females as described in Lehman et al. (2008). After nests hatched we located radio-marked females and their broods 5-6 days/week primarily by direct observation. Visual observation of poults May through August, 2001-2003, were used in poult survival analyses.

Poult Survival Analyses

We estimated poult survival ($\hat{S}$) from the initial number of poults that hatched from successful nests to the number surviving to 4 wks posthatch. Initial number of poult: was determined at each successful nest site based on egg shell and membrane remains Poults were counted at 1 wk, 2 wks, and 4 wks posthatch. If poults were found dead, necropsy of carcasses determined cause of death, and we classified mortality as mammalian predation, avian predation, or weather-related. Death was attributed to predation when examination of carcasses revealed hemorrhaging accompanied by puncture wounds. When necropsy of poults did not reveal wounds or injuries that suggested predation, we concluded the mortalities were likely the result of weather conditions.

Poults 1 wk of age were counted by observing broods feeding in open areas

or by counting poults observed at ground roosts (Thompson 2003). For ground roost observations, observers would watch the female and poults leave the ground roost site immediately after sunrise to obtain counts. Poults were counted 2 and 4 wks posthatch by visually observing broods while foraging in open areas; however, if dense vegetation hampered observations, broods were flushed to count poults (Glidden and Austin 1975, Vangilder et al. 1987, Hubbard et al. 1999). Broods may form crèches after poults reach 2 wks of age and is fairly common after poults reach 4 wks of age (Vangilder and Kurzejeski 1995). When radio-marked females with broods form creches it is difficult to differentiate individual females and their poults during the day so we counted these poults in late evenings or early mornings while they roosted in trees with the hen. On several observations, we noted broods would group together but were composed of slightly different age classes. Our roost observations indicated similarly aged poults would roost with the brood hen, suggesting we were counting the correct number of poults per female with this method.

We estimated poult survival using a modified Kaplan-Meier model (Kaplan and Meier 1958, Flint et al. 1995). This method allows interchange of individuals among broods and relaxes the assumption that poults within broods have independent survival probabilities. The modified model uses repeated observations of radio-marked adult females and their poults (Flint et al. 1995). We compared poult survival rates among years using a chi-square hypothesis testing procedure (Sauer and Williams 1989) using the program CONTRAST (Hines and Sauer 1989). End-point poult survival distributions were compared between age classes (adults and yearlings) of females using a *Z*-test described by Pollock et al. (1989). Significance level was set at $\alpha = 0.10$ for all comparisons. We selected $\alpha = 0.10$ since the 0.05 level can fail to identify comparisons that might be relevant (Hosmer and Lemeshow 2000).

Relationship of Weather to Survival of Poults

We obtained weather data from the nearest of five weather stations (National Climatic Data Center 2001-2003) in or adjacent to our study area. Because precipitation can be patchy from convection storms, daily precipitation represents an approximation at brood sites.

Weather variables for each individual brood survival interval included: heating degree days (HDD) (Roberts and Porter 1998a) calculated as HDD = 11 °C – average of the maximum and minimum temperature for each day; HDD = 0 if the average temperatures were ≥ 11 °C. HDD values were averaged for the number of days during the survival interval. Maximum, minimum, and average daily temperatures during a 24-hr period for days in the survival interval were also averaged. Total amount of precipitation and number of precipitation events (days with rain) were summed over the survival interval.

Temperatures < 11 °C in combination with precipitation can cause weather-related mortality in poults, particularly for poults < 15 days of age (Healy and Nenno 1985). Therefore, we also calculated a cold-wet index, which was calculated as 11 °C – the minimum temperature on the coldest day during the interval multiplied by the amount of precipitation on that day. If multiple days had the same minimum temperatures with precipitation, then the day with the most precipitation was used. When no days received precipitation during the interval the cold-wet index was given a 0. Values were summed for the interval between successive observations.

We modeled poult survival with several weather covariates through 15 days of age using generalized estimating equation (GEE) models with repeated measures (PROC GENMOD, SAS Version 9.01, 2005) using the information-theoretic approach (Burnham and Anderson 1998, 2002). Models were ranked using the Quasilikelihood under the Independence model Criterion with variance inflation factor statistic (QIC_u) (Pan 2001), which is

comparable to Akaike's information criterion comparing models fit with likelihood-ba ed methods (Burnham and Anderson 2002). For model selection uncertainty, we model-averaged the best ranking models with ΔQI_u values ≤ 2 (Burnham and Anderson 2002).

Relation hip of Weather to Poult:hen Ratio

We obtained annual poult:hen ratios compiled by the DGFP from 1971 through 2006 (unpublished data, DGFP, Rapid ity). DGFP collects ratio data from field staff opportunistically with visual ob ervations from the entire area of the Black Hills. We estimated the primary brood rearing period to be during the month of June based on observations from this study (unpublished data, South Dakota State University) and another conducted by Rumble and Anderson (1996) in the central Black Hills. We obtained weather data from three weather stations spread across the Black Hills for the period 1971-2006 (National Climatic Data Center 1971–2006).

We averaged weather station values for the month of June and used these data to analyze relations of poult:hen ratios to number days with precipitation events, number of days with precipitation events where average temperature was < 11 °C, and a June cold-wet index. The June cold-wet index was calculated as follows: for days in June in which minimum temperature was < 11 °C and precipitation occurred that day, we multiplied the difference between the minimum temperature and 11 °C by the precipitation on that day. For days in June that received no precipitation, or for day in which minimum temperature were > 11 ° and precipitation o curred that day, the daily value were given a 0;values greater than 0 were averaged for the month of June. We then u ed linear regression to estimate the relations between poult:hen ratio and these June weather variables using PROC REG (SAS Version 9.01, 2005).

RESULTS

Poult Survival to 4 Weeks

Fifty-seven female turkeys (52 adults, 5 yearlings) hatched 841 poults from 2001-2003. Years combined, poults reared by yearling female turkeys had lower (Z = 1.99, P=0.05) survival ($\hat{S}$) (n=47 poults, $\hat{S}$=0.11±0.10 [E]) than poults rai ed by adult females (n=794 poults, $\hat{S}$=0.33 ± 0.05 [SE]) to 4 wks posthatch. Poult survival rates at 1, 2, and 4 wks posthatch did not diffe r ($\chi_2^2 \leq 1.02$, $P > 0.60$) among years for poults raised by adult females (Table 1). Survival of poults hatched from first nest attempts (n = 515 poults, $\hat{S}$=0.26 ± 0 05 [SE]) was lower (Z – 1.65, P – 0 10) than survival of poults hatched from renests (n 279 poults, $\hat{S}$ = 0.46 ± 0.11 [SE]) at 4 wks posthatch.

Relationship of Weather to Survival of Poults

Six model exhibited support for predicting poult survival with weather covariates ($\Delta QIC_u < 2.0$). The model with the greatest support included age of poults (positive) and precipitation events (negative) (Fig. 1). The second best model included

Table 1. Poult survival ($\hat{S}$ ± standard error [SE]) at 1-, 2-, and 4-wk posthatch intervals for Merriam's broods reared by radio-marked adult females in the southern Black Hills, South Dakota, 2001–2003.

		Survival at Posthatch Intervals				
Year	n a–n b	0–1 ± SE	n c	0–2 ± SE	n d	0–4 ± SE
2001	213–92	0.43 ± 0.21	67	0.32 ± 0.20	49	0.23 ± 0 16
2002	243–122	0.51 ± 0.07	84	0.35 ± 0.10	81	0.33 ± 0.09
2003	338–147	0.44 ± 0.08	142	0.42 ± 0.08	135	0.40 ± 0.08
Pooled Years	794–361	0.46 ± 0.06	296	0.37 ± 0.06	265	0.33 ± 0.05

a – initial number of poults alive that left the nest bow
b – number of poults alive at 1 week of age
c – number of poults alive at 2 wee s of age
d – number of poults alive at 4 wee s of age

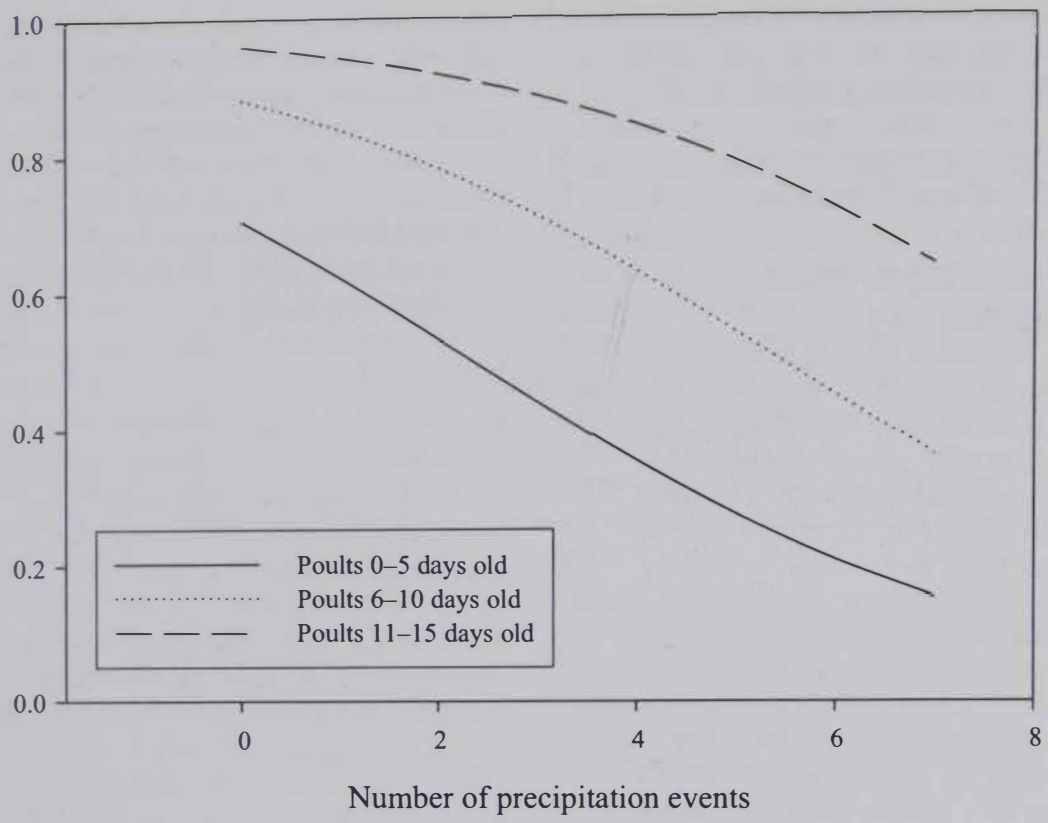

Fig. 1. Predicted survival of poults during 3 intervals (0–5, 6–10, 11–15 days post-hatch) with number of precipitation events that occurred during brood-rearing for Merriam's wild turkeys in the southern Black Hills, South Dakota, 2001–2003.

age of poults (positive), precipitation events (negative), and the interaction of age with the cold-wet index (Table 2). The interaction of age with the cold-wet index indicated younger poults were more susceptible to death by cold and wet events than older aged poults (Fig. 2). The covariates age of poults and precipitation events occurred in three of the models considered having support and the cold-wet index was included in four of the models. Due to model-selection uncertainty the parameter estimates for covariates from the top six models were averaged (Table 2).

Additionally, we found 11 dead poults while locating broods with radio-telemetry. Necropsies revealed poults died from hypothermia and we provide the weather data associated with the day the mortality occurred (Table 3). Mean 24-hr precipitation during the 11 weather related mortalities was 1.4 cm (SE = 0.7) and mean 24-hr minimum temperature was 1.5 °C (SE = 3.2).

Relationship of Weather to Poult:hen Ratios

Poult:hen ratios (1971-2006) were not correlated with number of days with precipitation during June ($\beta = -0.17$; $F_{1,35} = 1.04$, $P = 0.32$), nor number of days with precipitation events where average temperature was < 11 °C ($\beta = -0.28$; $F_{1,35} = 3.12$, $P = 0.09$). However, poult:hen ratios were correlated with the June cold-wet index ($Y = 5.48 - 0.15$ [Jun cold-wet index], $\beta = -0.60$; $F_{1,35} = 19.40$, $P < 0.01$) (Fig. 3). Cold-wet index values ≥ 10 for the month of June typically had ratios with fewer poults/female (≤ 3), whereas index values that were < 5 indicated ratios with more poults per female (≥ 5).

Discussion

Poult survival and recruitment are of major importance to maintaining wild turkey populations (Vangilder 1992); however, information on survival of Merriam's turkey

Table 2. General estimate equation models predicting poult survival through 15 days of age for Merriam's turkeys in the southern Black Hills, South Dakota, 2001–2003. Number of parameters (K), Quasilikelihood under the Independence model Criterion with variance inflation factor (QIC_u), Kullback-Leibler distances rescaled as simple differences (ΔQIC_u), Akaike weights (w_i), and evidence ratios (ER). Only the top six models are presented due to their weight of evidence ($\leq 2\ \Delta QIC_u$) and model averaged coefficients with variance are presented at the bottom.

Poult survival models	K	QIC_u	ΔQIC_u	w_i	ER
$\hat{S}$ = 0.19 + 0.23 (Age) – 0.37 (Precipitation events)	3	59.93	0.00	0.23	1.00
$\hat{S}$ = 0.17 + 0.23 (Age) – 0.34 (Precipitation events) – 0.002 (Age x Cold-wet index a)	4	60.77	0.84	0.15	1.52
$\hat{S}$ = 0.37 + 0.21 (Age) – 0.30 (Precipitation events) – 0.04 (Cold-wet index a)	4	61.00	1.07	0.13	1.71
$\hat{S}$ = – 0.26 + 0.24 (Age) – 0.01 (Age x Cold-wet index a)	3	61.33	1.40	0.11	2.01
$\hat{S}$ = 1.51 – 0.08 (Cold-wet index a)	2	61.60	1.67	0.10	2.30
$\hat{S}$ = 0.16 + 0.23 (Age) – 0.38 (Precipitation events) + 0.04 (HDD b)	4	61.62	1.69	0.10	2.33
Average $\hat{S}$ = 0.26 + 0.16 (Age) – 0.21 (Precipitation events) – 0.001 (Age x Cold-wet index a) – 0.01 (Cold-wet index a) + 0.004 (HDD b) (variance [$\hat{S}$] = 0.04)					

a – the cold-wet index was calculated as 11°C – the minimum temperature on the coldest day during the interval multiplied by the precipitation that occurred that day

b – heating degree days (HDD) is calculated on the Celsius scale as HDD = 11°C – average temperature if average temperature < 11°C, or HDD = 0 if average temperature ≥ 11°C, where average temperature is the mean of daily minimum and maximum temperatures

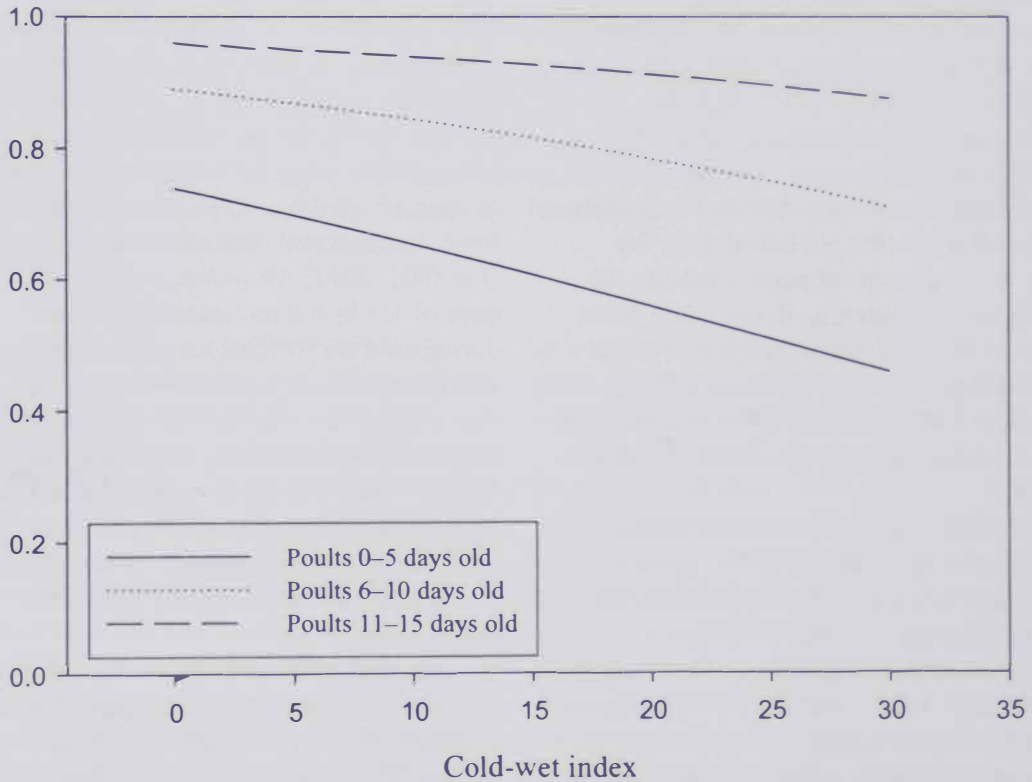

Fig. 2. Predicted survival of poults during 3 intervals (0–5, 6–10, 11–15 days post-hatch) with a cold-wet index during brood-rearing for Merriam's wild turkeys in the southern Black Hills, South Dakota, 2001–2003. The cold-wet index was calculated as 11°C – the minimum temperature on the coldest day during the interval multiplied by the precipitation that occurred that day.

Table 3. Relationship of weather data and Merriam's turkey poult mortalities investigators found dead from weather related death in the southern Black Hills, South Dakota, 2001–2003.

				Poult mortality events				
Date	n a	Age in Days	Prec. events b	Precip. c	Minimum temp. d	Cold-wet index e	HDD f	Predicted survival g
3 Jun 2001	2	1	2	1.93	−2	25.09	13	−0.22
4 Jun 2002	2	1	2	1.90	5	11.40	6	−0.10
4 Jun 2002	2	2	2	1.90	5	11.40	6	0.05
6 Jun 2003	1	1	2	0.50	−1	6.00	12	−0.02
6 Jun 2003	3	3	5	0.50	−1	6.00	12	−0.34
7 Jun 2003	1	1	2	1.90	3	15.20	8	−0.14

a – number of poults investigators found dead from weather related mortality
b – number of precipitation events that occurred from hatch to death
c – precipitation (cm) that occurred 24 hours before poults were found dead
d – minimum temperature (°C) that occurred 24 hours before poults were found dead
e – the cold-wet index was calculated as 11°C – the minimum temperature on the coldest day during the interval multiplied by the precipitation that occurred that day
f – heating degree days (HDD) is calculated on the Celsius scale as HDD = 11°C – average temperature if average temperature < 11°C, or HDD = 0 if average temperature ≥ 11°C, where average temperature is the mean of daily minimum and maximum temperatures
g – predicted survival using model averaged coefficients (= 0.26 + 0.16 [Age] – 0.21 [Precipitation events] – 0.001 [Age x Cold-wet index] – 0.01 [Cold-wet index] + 0.004 [HDD]) and variables associated with mortality

poults is limited to a few studies (Rumble et al. 2003). Survival of Merriam's poults to 4 wks of age ranged from 36–59 percent (36% in Wyoming [Hengel 1990], 36–59% in Arizona [Wakeling 1991], 43% in southcentral South Dakota [Flake and Day 1996]). We consider poult survival (33%) at 4 wks posthatch in the southern Black Hills low relative to other published data. We observed 54 percent of poult mortality the first week after hatching in our study. Most poult mortality occurs before poults reach 2 wks of age (Glidden and Austin 1975, Vangilder and Kurzejeski 1995, Roberts and Porter 1998a, Lehman et al. 2001, Spears et al. 2007).

Precipitation events in combination with cold temperatures < 11 °C reduced survival of Merriam's turkey poults in the 15-day posthatch period. We found 11 dead poults during the course of locating broods with radio telemetry following cold and wet weather events; eight of which were 1–2 days old and found near nests. Three other poults ~ 3 days old were found dead at sites where we observed broods foraging. Necropsy did not reveal wounds or injuries that suggested predation, so we concluded these mortalities likely resulted from weather conditions. Precocial young of galliform birds in the first week after hatch have poorer insulation, poorer thermal regulation, and relatively high surface area to volume ratio than older young (Schmidt-Nielsen 1997). On the other hand, precocial young of two other galliform species seem to have adapted to cold by maintaining lower body temperatures than older young (Pis 2001, 2002). However, poults < 10 days of age brood underneath females during cold wet conditions and may be less susceptible to cold and wet weather than older poults that have become too large to brood under females (Healy and Nenno 1985). Our observations and model predictions indicated poults < 5 days of age were susceptible to mortality from cold and wet conditions despite protection by the brood hen.

Accumulation of body mass from 1 to 7 days posthatch is significantly less than during 8–14 days posthatch (Healy and Nenno 1980). Thus, poults ≤ 1 wk of age may be hindered energetically in being able to survive cold and wet weather events even though they have a reserve supply of yolk available the first few days after hatch. Survival of eastern turkey poults to

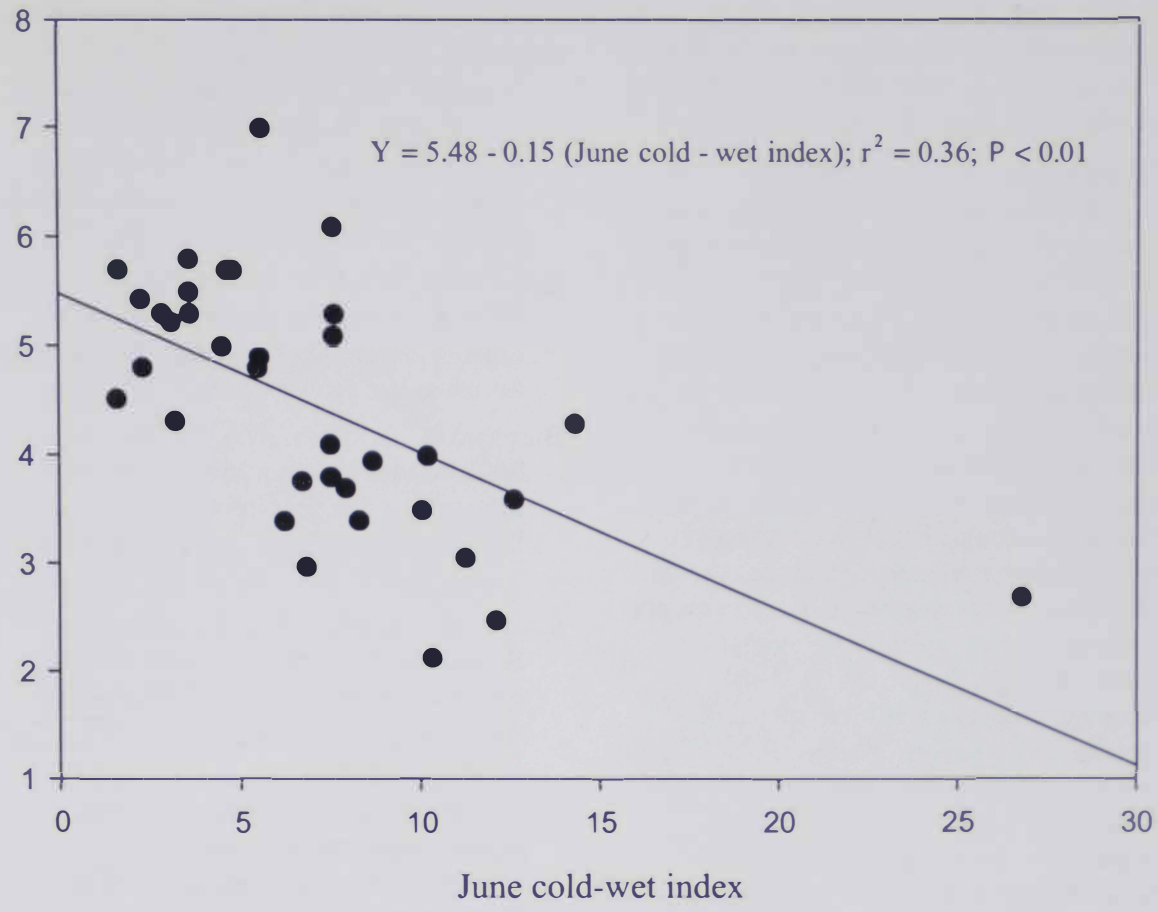

Fig. 3. Association of poult:hen ratio data and a June cold-wet index variable from 1971–2006 for Merriam's turkeys in the Black Hills, South Dakota. The June cold-wet index was calculated as follows: for days in June where the minimum temperature was < 11 °C and precipitation occurred that day, the difference between the minimum temperature and 11°C was multiplied by the precipitation on that day. June index values were correlated with poult:hen ratios using linear regression.

2 wks posthatch at the northern extent of their range was also negatively associated with colder temperatures and increased precipitation (Porter and Roberts 1998a).

The relationship between long-term poult:hen ratios and inclement weather does suggest a negative association between cold and wet weather and survival of poults. Extreme cold and wet weather coincided with years when poult:hen ratios were usually < 3. However, the strength of the relationship was marginal ($r^2 = 0.36$), which was most likely due to the scale at which weather variables were related to poult:hen ratios. Field staff opportunistically collected ratio data over a large area, and precipitation from convection storms are often patchy in the Black Hills. Such a coarse-scale evaluation of weather variables with poult:hen ratios does not provide as much information as a fine-scale approach.

Despite the effects of weather, we suspect that an appreciable portion of the unexplained variability in survival of poults was the result of predation. We observed a golden eagle (*Aquila chrysaetos*) prey on two poults that were 6 days of age hatched from a radio-marked female (Lehman and Thompson 2004). Mammals were the most common predators of turkey nests (Lehman et al. 2008), and predation on poults could be amplified during periods when poults are wet. Precipitation increases bacterial activity on the skin of turkeys and produces more odors during incubation possibly facilitating olfaction by predators (Syrotuck 1972,

Roberts and Porter 1998b). During our study we continued to locate females with poults through 28 days posthatch but mortality was much reduced after 15 days of age.

Management Implications

Reduced nesting success during wet springs (Lehman et al. 2008), and reduced survival of poults resulting from cool and wet conditions during June will likely severely reduce recruitment in Merriam's turkey populations. Precipitation can be spotty over the Black Hills and a coarse-scale weather based index that tracks precipitation events over a large area may not be as valuable a tool for managers as a fine-scale based index. Managers should relate individual weather station parameters to specific areas occupied by turkeys and such a fine-scale approach will better estimate production of Merriam's turkey populations if survey or radio telemetry data are not available. Recruitment information will give managers more flexibility in adjusting season lengths and bag limits immediately after years of poor or good reproduction.

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Abstracts

Biological Sciences – Aquatic

Montana Chapter of the American Fisheries Society
41st Annual Meeting

Warming to the Future: Preparing for the Potential Effects of Climate Change on Montana's Aquatic Resources

February 12-14, 2008

Billings, Montana

2008 Invited and Contributed Paper Abstracts

Over 180 members of the Montana Chapter of the American Fisheries ociety gathered in Billings, Montana, February 12-14th for the 41st annual meeting of the hapter. The meeting was organized around the theme of "*Warming to the Future: Preparing for the Potential Effects of Climate Change on Montana's Aquatic Resources*" and the opening plenary session included six very informative papers discussing science and policy related to this topic **Mike Phillips** and **Dave McGinnis** set the stage by discussing the changing broad scale climate patterns and potential future climate trends and policy needs. The remaining plenary speakers —**Bruce Anderson, Robert Gresswell, Jack Williams, and Bruce Riemen**—brought the issue to ground and focused on the implications of a changing climate on habitat, stream temperatures, and native fishes. A consistent message to a somber audience was that climate change will likely be the biggest issue that aquatic biologists, managers, researchers, and practitioners have ever faced. Consider this: along with 1998, the first five years of the twenty first century were the hottest on record; arctic sea ice has lost nearly half its average thickness since 1950; greenhouse gas concentrations in the atmosphere are approximately 40% higher than pre-industrial levels; growing seasons at higher latitudes are approximately two weeks longer than in the 1950s; and the list goes on. Recognizing much uncertainty, and in some ways incredulity regarding the science of climate change, it is becoming increasingly clearer that change is afoot. What that change means for Montana's aquatic ecosystems remains a difficult question. The plenary session was organized in attempt to catalyze our members to keep this issue in the forefront of their professional activities. How can we as administrators, managers, and researchers better prepare for climate change related issues that seem an inevitable future? Will we be able to respond to a public and constituencies looking to us for guidance and solutions? Is there data that can be collected, research that can be conducted, policies that can be enacted, or activities and traditions that can be changed that will allow us to be better prepared and more proactive to address this issue? Of course there are, but they may not be easy.

The following abstracts presented at the 2008 annual meeting, which cover a range of topics from climate change to big river management, from native fish management and restoration to research on non-game fishes, demonstrates the wide reaching, important and timely work conducted by Montana's fisheries professionals. Based on this and past meetings,

there is little doubt that the dedicated individuals, agencies, and organizations represented by the Montana Chapter of the American Fisheries Society will continue to strive to meet the challenges posed by a changing future.

Carter G. Kruse, President. Montana Chapter of the American Fisheries Society.

Climate Change impacts on Montana Waters

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Scientific consensus suggests that climate change is real and that we will soon need to address the ecological changes that will result. While normal weather changes give most of us a sense of uncertainty regarding how climate change might impact on Montana, the long-term picture for Montana can be developed well utilizing climate models and associated analysis of climate change impacts. This talk will describe our current knowledge and predications for Montana's future climate with a focus on fishery concerns. The general science behind climate change simulations will precede a description of how temperature and precipitation are likely to be different in the future. The goal of this talk is to provide a background of potential climate change that may impact on regional fisheries.

Global Warming, Restoration, and the Rocky Mountain Front

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Time will settle any on-going debate about the magnitude or meaning of global warming. In the meantime, restoration specialists are faced with prioritizing actions to maximize potential benefits to fisheries, stream systems, and water quality. The biological consequences of potentially elevated water temperatures, changing water yield, and reduced snowpack have significant implications both for resource management and allocation of limited funding. Data from the Rocky Mountain Front shows trends in reduced water yield and snowpack. In-stream temperature monitoring shows average and maximum temperatures well above thresholds considered sustainable for salmonids. Competition for irrigation water increases pressure on limited supplies and reduces in-stream flow. What happens if the environment becomes yet warmer, or if we respond with assertive restoration? The temperature model SNTEMP provides a means to evaluate an array of potential restoration actions including alteration of stream W/D ratio, baseflow discharge, riparian shading, and groundwater recharge. Application of this model along the Rocky Mountain Front provides a potentially enlightening perspective on our collective restoration focus. Add a couple degrees Fahrenheit to the mean air temperature, or increase riparian coverage 20 percent. Reconsider the in-stream results and your priorities as fisheries manager or stream restoration specialist.

Conserving and Restoring Native Trout in the Face of Climate Change, Invasive Species and Development

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Evidence suggests that factors such as climate change and a century of fire suppression are altering fire regimes in some vegetation types of the western USA, and the probability of large stand-replacing fires has increased in those areas. For example, over 100 million acres have been burned by wildfire in the West during the last 20 years. It appears, however, that even in the case of extensive, high-severity fires, local extirpation of fishes is patchy, and recolonization is often rapid. Lasting detrimental effects on fish populations have been limited to areas where native populations have declined and become increasingly isolated because of anthropogenic activities. Unfortunately, this situation is exacerbated by decreasing water availability at a time when demand is increasing. Furthermore, the potential of invasive species to expand under these altered habitat conditions is poorly understood. Despite incomplete knowledge of the effects of climate change in aquatic systems, it is apparent that managers must begin to develop a broad-based management strategy that focuses on protecting remaining native fish populations and associated habitat from further anthropogenic degradation and restoring degraded habitat and connectivity. Such a strategy will require a watershed-scale approach than integrates conservation and restoration activities throughout the stream network.

Potential Consequences of Climate Change to Persistence of Cutthroat Trout Populations

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Warmer water, changes in stream flows, and increasing frequency and intensity of disturbances are among the factors associated with climate change that are likely to impact native trout populations in the western U.S. We analyzed three of these factors—increased summer temperatures, uncharacteristic winter flooding, and increased wildfires—that are likely to affect broad-scale population persistence among subspecies of cutthroat trout, (*Oncorhynchus clarkii)*. Our models suggest that risk will vary substantially among and within subspecies. Up to 78 percent of currently occupied habitat of Bonneville cutthroat trout (*O. c. utah)*, 65 percent of westslope cutthroat trout (*O. c. lewisi)*, and 29 percent of Colorado River cutthroat trout (*O. c. pleuriticus)* will be at high risk from one or more of the three factors examined. Each subspecies contains two or more river ub-basins (Geographic Management Units) where all remaining populations either fail to meet basic persistence criteria and/or are at high risk from climate-associated impacts, indicating a high likelihood of genetic and life history losses within those areas. Stress from climate change is likely to compound existing problems associated with habitat degradation and introgression from introduced salmonids. Recognition of the increased risk from climate change may alter the management paradigm of isolation and require increased control efforts for invasive non-native species. Regardless of the management avenue chosen, more populations are likely to become isolated and vulnerable in the near future. We argue for early intervention within certain sub-basins to increase resistance and resiliency to at-risk populations and habitats prior to further disturbances associated with a rapidly changing climate.

Implications of Climate Change for Fishes in Headwater Streams: What's Changing and What Can We Do About It?

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Bruce Rieman has recently retired as a research scientist and program manager for the USDA Forest Service, Rocky Mountain Research Station in Boise, Idaho. He has 34 years experience in research, management and research program administration dealing with fishes, fisheries, and conservation biology. His work has extended throughout the Interior Columbia River Basin, but also has influenced aquatic natural resource management in much of the interior west. His most recent focus has been in collaboration with a team of physical and biological scientists investigating fish population dynamics, habitat relationships, and factors influencing persistence of local and regional populations. The implications of wildfire and climate change have been important elements of this work.

Is There Anybody Out There? Survival Estimation of Hatchery-Reared Pallid Sturgeon

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No recruitment of endangered pallid sturgeon (*Scaphirynchus albus*) has occurred in the upper Missouri River basin in at least 30 years and this species will likely be extirpated by 2024. Accordingly, the extant pallid sturgeon genetic pool is being preserved through captive propagation and stocking until habitat restoration permits re-establishment of self-sustaining populations. However, few recaptures of stocked fish and violation of model assumptions precluded evaluation of stocking programs over the past 10 years; no empirically derived survival estimates existed for hatchery-reared pallid sturgeon. We used a telemetry approach to develop a habitat-based sampling design that met model assumptions and yielded adequate recaptures to estimate survival of hatchery-reared pallid sturgeon stocked in the Yellowstone River. Telemetered fish appeared to preferentially select bluff pools and selectively sampling this habitat type resulted in catch rates (8.7 fish/hr or 1.6 fish/trammel net drift) 20 to 90 times greater than those of previous sampling designs. Apparent annual survival of three common stocking ages was estimated using Cormack-Jolly-Seber models. Probability of survival to age 2 of 13 month-old fish released in summer (0.19) was higher than that of 10 month-old fish released in spring (0.08) and 3 month-old fish released in autumn (0.01). Annual probability of survival for 13 month-old fish stocked in summer increased and stabilized (0.70) by age 4. Survival estimates for all stocking ages were lower than anticipated and suggest that stocking rates should be increased by an order of magnitude to meet current population targets and avoid local extinctions.

Effects of Varying Discharge on the Ichthyoplankton Assemblage in the Marias River, Montana

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Many lotic fish species use fluctuations in discharge as a cue for spawning. The effects of spring discharge variation on the spawning behavior of fish populations in the upper Missouri River have not been documented. Contrasting discharge events in the Marias River during the spring of 2006 and 2007 gave us the unique opportunity to study the response of ichthyoplankton density and richness to discharge variation. The objectives of this study were to examine spatial and temporal variation in the density of ichthyoplankton in the lower Marias River and to investigate the effects of varying discharge on the timing and location of spawning for resident fish species, especially sturgeon (*Scaphirhynchus* spp.). We sampled ichthyoplankton every four days in June and July of 2006 and 2007 at five sites in the Marias River, one site in the Teton River, and two sites in the Missouri River. Estimates of larval fish density varied temporally in the Marias River. Overall density of larval fish in the Marias River was greater in 2006 (0.206 fish/m^3) than in 2007 (0.089 fish/m^3). In 2006, sturgeon spawning occurred in the Marias River in conjunction with the spring hydrograph peak (134 m^3/s) when temperatures were between 15 °C and 20 °C, while no evidence of sturgeon spawning was documented in the Marias River in 2007 in absence of a spring hydrograph peak (15 m^3/s). These data suggest that increased discharge in the Marias River provides a spawning cue to sturgeon, while increasing overall ichthyoplankton density.

Mercury Dynamics in South Dakota Walleye: Water Level Fluctuations, Seasonal Variation and Reproductive Condition

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Consecutive years of high precipitation during the mid-1990s caused dramatic surface area expansions in many glacial lakes and wetlands of eastern South Dakota. In everal of these lakes, walleyes (*Sander vitreus*)and other game fishes were found to contain elevated mercury (Hg) concentrations (>1 µg/g). Using data from recent habitat surveys and state-wide Hg sampling, we explored relationships between physicochemical attributes of lakes and Hg concentrations in walleye. Lakes that experienced the greatest change in surface area (Δ ha) between wet (1999-2001) and dry (1975-1979) years contained walleye with the highest Hg concentrations. We collected walleye from two high Hg lake to determine if Hg concentrations fluctuate seasonally. Tissue Hg concentrations of walleye adjusted for length were significantly higher in the spring in both Bitter (42.9 %; $P < 0.008$) and Twin Lakes

(67.6 %; $P < 0.017$) compared to summer and fall samples. To evaluate factors affecting walleye reproduction, we compared reproductive characteristics between a low (Pelican Lake, mean Hg = 0.05 µg/g) and high Hg (Bitter Lake, mean Hg = 0.99 µg/g) lake. Mean monthly blood plasma concentrations of estradiol-17β and testosterone for both male and female walleyes were suppressed in fish from Bitter lake (high Hg) compared to Pelican lake (low Hg). To evaluate the influence of Hg on fertilization success, we conducted laboratory experiments to quantify effects of extrinsic (i.e., waterborne MeHg concentration) and intrinsic (i.e., Hg concentration of parental males) factors associated with Hg contamination. Fertilization success decreased significantly with increased waterborne MeHg concentration ($F_{[4,90]} = 70.5$, $P < 0.001$) and ranged from 28 percent at 1 mg/L to 65 percent at 0 mg/L. This study suggests that top-level predators in naturally contaminated lakes may be at risk for impaired reproductive success. Closely monitoring the relationship between walleye Hg concentration and recruitment dynamics would provide further insight into the toxicological effects of Hg on the reproductive success of walleyes.

What I Learned about Pallid Sturgeon on My Summer Vacation...A Summary of Findings From Reclamation-Sponsored Research In the Missouri and Yellowstone Rivers in Montana

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In support of Endangered Species Act consultation, Reclamation's Montana Area Office has been involved in several activities furthering the knowledge of pallid sturgeon (*Scaphirynchus albus*) in relation to Reclamation projects in the Missouri and Yellowstone Rivers. In the Upper Missouri River basin, responses by fish to a high spring flow in the Marias River in 2006 were measured and compared to a flat base flow in 2007. Responses included fish movements into the Marias River, movements in the Missouri River and increased production of larval fish and eggs in the Marias. Physical habitat monitoring showed a response in habitat formation via natural ecological processes such as sediment transport and woody debris movement in 2006. Radio telemetry data is indicating an area of the Missouri river that appears to be important to shovelnose and pallid sturgeon, possibly for staging or spawning that will be studied further. Sturgeon were captured on video in the Marias River using DIDSON technology, and information on spiny softshell turtles is also being collected. Other research efforts have been focused on developing fish passage on the Lower Yellowstone River near Glendive, Montana, and protecting fish from entrainment into the irrigation canal. Some of this work includes engineering design and sturgeon swimming studies. Larval pallid sturgeon were studied to investigate swimming endurance, impingement survival, screening effectiveness, and recovery of impinged fish from traveling fish screens.

Western Native Fishes Database; Species Status, Distribution, and Information Needs

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The Western Native Fishes Database is a project developed by the ative Specie Committee of the Western Division of the American Fisheries Society (WDAFS). The goal of the project is to compile the most recent information on approximately 300 fish specıe native to western North America including the anadian Provinces of British olumbıa and Yukon; the Sonoran, Chihuahuan, and Baja California orte States of Mexico; and the United States that include, or are west of, the continental divide; and Hawaii. Garcia and Associates (GANDA) completed the database design in the summer of 2004, data compilatıon ın 2006, and an extensive peer review in 2007. The database can be queried by species, regıon, or HUC. The WDAFS envisions the database being u ed to track regional status of native fishes and to assist agencies and biologists in developing management plans that extend beyond political boundaries. This presentation provides an update on the project to its potential audience, describe the peer review process, and solicit input on our next phase which will allow mapping in real time.

Milltown Reservoir Dam Removal and Sediment Excvat ion

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The Milltown Dam is located approximately seven miles east of Missoula, Montana, at the confluence of the Blackfoot and Clark Fork rivers and was originally constructed to provide hydropower-generated electricity for a major sawmill in 1907. In 190 , a major flood resulted in a widely-spread overbank condition that washed tailings from major copper mining operations in the Butte and Anaconda area, approximately 100 mi upstream of Milltown. The backwater condition created by the dam resulted in the deposition of an estimated 7 million cubic yards of sediment behind the reservoir. A portion of these sediments contained elevated concentrations of metals, particularly copper and arsenic. EPA listed the Milltown Reservoir Sediment Operable Unit (MRSOU) on the National Priorities List in 1982 based on arsenic detected in Milltown groundwater wells located adjacent to the reservoir sediments. In late 2004 EPA selected a remedial action for the MRSOU, which included removal of the dam and excavation of 2.2 million yards of contaminated sediments. Initial drawdown and construction for the first phase of the project began in June 2006. This presentation summarized design and construction strategy for removal of the dam, the work conducted to date and measure implemented to minimize impacts to the Clark Fork River fisheries.

Distribution, Life History, and Movements of Yellowstone Cutthroat Trout in the Upper Yellowstone River Drainage

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The Yellowstone Lake ecosystem has long been a stronghold for native Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri)*. However, recent declines in this assemblage, due to non-native lake trout (*Salvelinus namaycush)* and whirling disease, prompted fisheries investigations into the 1244-km^2 upper Yellowstone River watershed. The Yellowstone River is the largest tributary to Yellowstone Lake; however, because of its remoteness, little is known about the life-history of fishes using this watershed. During 2003- 2007 radio telemetry, electrofishing, and snorkeling were used to determine cutthroat trout distribution, life-history, and habitat use. Movements of 151 adults were tracked by aircraft and ground surveys. Cutthroat entered the river in April and migrated as far as 67 km to spawn. Spawning aggregations within the park were rare, found in only five locations. These sections were predominately runs with gravel substrate. Tagged fish typically spent < 3 mos in the river, the majority (72%) returned to the lake, 26 percent migrated downstream until signal loss, and 2 percent stayed in the river. Raft-mounted electrofishing and snorkeling of the main-stem Yellowstone River found 1.1 and 3.4 fish/km >200 mm respectively. The majority were found in 8 of the 39 sections surveyed. These sections contained pool habitats or runs/glides > 1.5m in depth, all contained woody debris. Densities of fish < 200 mm were 3.95 and 2.7 fish/km, respectively. Smaller fish were found in all habitats with the exception of pools. These data suggested that the majority of cutthroat trout in the Yellowstone River above Yellowstone Lake express a lacustrine-adfluvial life-history.

Landscape distribution and biological diversity of cutthroat trout in the Snake River headwaters, Wyoming

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We used a landscape scale approach to facilitate the synthesis of ecological, morphological, genetic, and life history information regarding the distribution and organization of Yellowstone cutthroat trout, (*Oncorhynchus clarkii bouvieri*) and fine spotted Snake River cutthroat trout, (*Oncorhynchus clarkia)* subspecies, in the Snake River headwaters of northwest Wyoming. Our work focused on the largely connected stream networks up and down stream of Jackson Lake dam. Systematic sampling allowed us to hierarchically analyze for morphological or geographic structuring from the stream reach

to basin scale. Differences in landscape distribution were observed, with the large- potted morphotype decreasing in occurrence along a north-south gradient. Multivariate analyses of spotting patterns can discriminate between the large-spotted and fine-spotted morphotypes, with < 10 percent misclassification rates. We were unable to genetically differentiate between the morphotypes using an 1150 bp region of the ND1-ND2 mitochondrial genome, however, two genetic clades and differences among drainages were apparent. We observed a range of mobility by cutthroat trout that exhibited resident and fluvial life histories. Ranging behavior of fluvial migrants varied from < 5.0 km in headwater streams, to > 40.0 km in larger rivers with complex seasonal movements among several streams. As climate changes, future conservation of cutthroat trout in the Snake River headwaters should continue to emphasize maintenance of phenotypic variability, protection of existing genetic structure, as well a restored habitat connectivity to sustain life history variability. Conserving the biological diversity exhibited by these native cutthroat trout need not be encumbered by taxonomic distinction, especially given that a changing climate may favor one or neither of the morphotypes.

Evaluating Effects of Small Dam on Migratory Bull Trout in the Clearwater River Drainage, Montana

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Dams are well known for their negative impacts on fish populations. As a result, dam removal decisions are becoming increasingly common. In collaboration with Montana Fish, Wildlife and Parks and the USDA Forest Service, we are using the Clearwater River Drainage in West-Central Montana to explore effects of small dams on migratory bull trout (*Salvelinus confluentus*). We captured 41 adfluvial bull trout below two small dams, implanted radio tags (n = 17) or pit tags (n = 24), and released them above the dams. We are monitoring movements of these radio-tagged fish and other bull trout tagged in the surrounding lakes. These dams are upstream migration barriers. Fifteen of 17 radio-tagged fish we moved over the dams, as well as several fish tagged in the lakes swam into a spawning tributary and presumably spawned. We confirmed two additional spawning tributaries where bull trout recruitment is likely due to migratory fish. The relatively large number of bull trout captured below the dams compared with redd counts in the spawning tributaries provides evidence that these barriers may have large impacts on population sustainability. Post-spawning mortality rates were high and attributed to low water conditions, high cost of spawning, and predators. Our ongoing research will further monitor mortality rates and work to quantify the impact of these barriers on bull trout in the drainage. This information will contribute to the deci ion-making process involving dam modifications or removal to balance the benefits of upstream passage for native fish with the risk of expansion by undesirable non-native fish.

The Influence of Beaver on Brook Trout Invasion and Native Westslope Cutthroat Trout Displacement in Rocky Mountain Streams of Southwestern Montana

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Invasion of ecosystems by nonnative species is often responsible for reshaping natural biological communities. In the Rocky Mountains, brook trout (*Salvelinus fontinalis*) invasion has been implicated in the decline of westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), a native species of special concern in Montana. Although research has established that negative interactions between these species likely occur at the juvenile stage, there remain gaps in our understanding of the landscape factors that influence the extent of invasion, and resulting cutthroat declines. For example, beaver (*Castor canadensis*) are capable of altering stream habitat characteristics considerably, but we do not know how beaver disturbance influences brook trout invasion success, and the consequences for native cutthroat trout. To address this, I used temperature loggers, mark-recapture, and habitat surveys to establish how beaver affect (i) brook and cutthroat trout distributions within watersheds, and (ii) species interactions between cutthroat and brook trout. Distribution and temperature data show that beaver-induced stream warming sustains brook trout invasion at higher elevations, while brook trout presence acts to reduce cutthroat trout growth rates. Ongoing analyses of growth rates from scales, and examination of demographic rates of both species will lend greater insight into how beaver impact this system.

Assessing Distribution and Abundance Patterns of Cutthroat and Brook Trout Using Thermal Data Coupled with Physiological Models of Fish Growth

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Distributions and abundances of native westslope (*Oncorhyncus clarkii lewisi*) and Yellowstone cutthroat trout (*O.c.bouvieri*) have declined in Montana during the last century. Nonnative salmonids and habitat and climate change have been implicated in this decline. Cutthroat trout in Montana are currently restricted primarily to higher elevation stream habitats, where mountain ranges appear to function as island refuges, especially within the upper Missouri basin. Preliminary analyses indicate restriction of cutthroat trout to upper elevation refuges might be partially explained by thermal gradients. Competitive interactions between cutthroat and nonnative salmonids may be partially regulated by temperature. We explored methods for evaluating whether temperature might help explain distribution and abundance patterns of cutthroat and brook trout at over 1000 sites we sampled throughout the Northern Rocky Mountains. Patterns of cutthroat trout occupancy appeared associated with elevation and air temperature predictions at various scales, from state-wide to the stream

scale. We used an existing thermal model to predict daily water temperatures. We linked thi model with relationships between fish growth and water temperature developed in laboratory studies to integrate the potential influence of the thermal regime on fish at each sample site. We collected water temperature data at over 100 sites through several years to develop, validate, and calibrate this thermal model. If thermal information significantly contributes to our understanding of the current distributional patterns of these species, managers can use these relationships to target areas for cutthroat trout conservation that have the be t likelihood for success. Managers could also use these models to locate and conserve stream for future cutthroat trout conservation under the assumption of continued global warming.

Interactions Between Bull Trout and Lake Trout for Simulated Cover Habitat

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Population-level declines of bull trout (*Salvelinus confluentus*) have been observed following establishment of lake trout in lake ecosystems. The mechanism responsible for these declines is unknown; however, competitive interactions between these two species of char may occur at one or more ontogenetic stages. Cover habitat in lakes (e.g., interstices of rocky substrate) may allow detection of food resources while providing protection from predators for juvenile bull and lake trout. We examined use of simulated cover habitat in the laboratory to determine if bull trout and lake trout behavior reflects cover use in the presence of conspecifics, and if bull trout and lake trout alter behavior in the presence of heterospecifics. Behavioral observations were made to determine if fish were 1) using cover, 2) stationary on the bottom of the tank, 3) stationary in the water column, or 4) swimming. In the presence of conspecifics, on average bull trout used cover habitat 38 percent of the time, were stationary on the bottom 33 percent, swam 15 percent, and were stationary in the water column 9 percent. In the presence of conspecifics, on average lake trout used cover habitat 2 percent of the time, were stationary on the bottom < 1 percent, swam 38 percent, and were stationary in the water column 58 percent. Neither bull trout nor lake trout responded differently in the presence of heterospecifics. Bull trout and lake trout had essentially opposite behavioral responses in the presence of simulated cover habitat. Therefore, these data provide no support for the hypothesis that these species compete for cover habitat.

Effects of Fire on Stream Temperatures in the Bitterroot River Basin, Montana

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Stream temperature is an important abiotic factor affecting the distribution of native trout. Much of our understanding of the effects of wildfires on stream temperatures is derived from individual case studies. In 2000, major wildfires burned in the Bitterroot River Basin, Montana. We used a Control-Impact design to examine immediate effects of wildfire on maximum stream temperature and a Before-After-Control-Impact design to evaluate recovery of maximum summertime stream temperatures after wildfires. We examined temperature data from 33 streams at three kinds of sites: those in largely unburned watersheds, those downstream of burns, and those within burns. To account for potential seasonal differences in recovery, we analyzed August and September separately. During the fire, there were no significant increases in maximum water temperature in sites located within or downstream of burns. One year after the fire, there was a significant fire effect in August (1.7°C ±0.33) and September (2.3°C ±0.16) at sites located within the burned area compared with reference sites. But, there was no significant increase in temperature in sites downstream of burns compared to reference sites. We saw a significant increase in temperature for all treatment groups over the last 12 years indicating regional warming. Maximum summertime temperature increased 0.4°C (95% CI±0.33), 1.1 °C (95% CI ±0.63), and 2.8 °C (95% CI ±0.87) in reference, below-burn, and within-burn areas, respectively. There was no recovery of stream temperatures in burned areas five years after wildfires. These results are similar to other studies where wildfires have localized, long-term impacts on stream temperatures.

Evaluating Surgical Implantation of 23-Mm Passive Integrated Transponder (PIT) Tags in Arctic Grayling

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Passive integrated transponder (PIT) technology is useful for evaluating movement, habitat use, and the dynamics of fish populations and communities. One distinct advantage of this approach is the ability to collect information throughout the life of individually identifiable fish using passive (remote) monitoring sensors (fixed and portable antennas). Despite widespread use of PIT tags in a variety of salmonids, some questions remain concerning post-implantation survival in some species. To determine potential negative effects of using PIT tags in Arctic grayling (*Thymallus arcticus*), we (1) implanted 23-mm

half-duplex tags in Arctic grayling and measured subsequent short-term mortality, and (2) reviewed literature concerning the effects of using PIT tags in fish. We PIT-tagged grayling from 158 to 340 mm in total length, and after four days, we observed 100-percent survival and 100-percent retention of PIT tags. Furthermore, published reports suggested that survival and growth of PIT-tagged salmonids ≥ 100 mm does not differ significantly from controls. These results support the assertion that PIT-tagging Arctic grayling >150 mm will not negatively affect grayling populations or research results. Subsequent research to determine the minimum size of Arctic grayling that can be implanted with 23-mm PIT tags without negative effects is warranted.

Spatial and Temporal Dynamics of Spawning Between Native Westslope Cutthroat Trout, Introduced Rainbow Trout, and Their Hybrids, With Implications for Hybridization and Loss of Adaptation

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Populations of many native salmonids in western orth America are threatened by introgression with introduced rainbow trout (*Oncorhynchus mykiss*; RBT), yet little is known about the reproductive factors influencing the spread of hybridization in the natural environment. We used radio telemetry to assess spatial and temporal spawning distributions of native westslope cutthroat trout (*O. clarkii lewisi*; WCT; $N = 27$), introduced RBT ($n = 51$) and their hybrids ($n = 47$) in the upper Flathead River system, Montana and British Columbia, from 2000 to 2007. Radio-tagged trout moved upriver towards spawning sites as flows increased during spring runoff and spawned in 29 tributaries. WCT migrated greater distances and spawned as flows declined in headwater streams dominated by snowmelt runoff, whereas RBT and RBT-hybrids (backcrosses to RBT) generally spawned earlier in low elevation streams fed by springs or headwater lakes; WCT-hybrids (backcrosses to WCT) spawned intermediately in time and space. Both hybrid groups spawned over relatively long time periods that produced temporal overlap with spawning WCT in most years. Spatial overlap between parental species occurred in four streams (two streams where F_1 hybrids and two streams where RBT spawned in the same areas used by WCT) and spawning sites used by both hybrid groups overlapped in 17 streams. One stream, Abbot Creek, supported a relatively high proportion of spawning by RBT and RBT-hybrids (47%), and a genotypic gradient was found extending upstream from the site, indicating that this location is likely the ultimate source of introgression in the study area. The spatial distribution of RBT, RBT-hybrids, and F_1 hybrids indicates hybridization is being promulgated upstream by long distance movement of individuals with high amounts of RBT admixture, but the spatial distribution of later-generation backcrosses suggests stepping-stone invasion may also be an important mechanism for spreading nonnative genes, corroborating conclusions from previous genetic studies. Our data suggest that (1) spatial and temporal overlap was occurring in the lower drainage, but streams in the middle and upper drainage still provided reproductive segregation; (2) introgression erodes discrete spawning behavior of migratory WCT, which will likely lead to lead to loss of local adaptation; and (3) the spread of hybridization is likely to continue and

genomic extinction is imminent if hybrid populations with high amounts of RBT admixture are not reduced or eliminated.

Local-Habitat, Landscape, and Biotic Factors Associated with the Distribution of Hybridization Between Native Westslope Cutthroat Trout and Introduced Rainbow Trout in the Upper Flathead River System

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Invasion of nonnative fishes in freshwater systems is often facilitated through the interaction of environmental and biotic factors operating at multiple spatial and temporal scales. We evaluated the association of local-habitat features, large-scale landscape characteristics, and biotic factors with patterns of occurrence and degree of hybridization between native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*; WCT) and nonnative rainbow trout (*O. mykiss*; RBT) in 35 streams of the upper Flathead River system in Montana., and British Columbia, Canada. The presence or absence of hybridization and the proportion RBT admixture for each sampled population was estimated using seven diagnostic microsatellite loci. Local-habitat features included measures of stream size, gradient, and elevation. Landscape variables included measures of mean and maximum summer water temperature and of land disturbance (upstream road density and the number of upstream road crossings). The abundance of trout within sampled sites and distance to the source of hybridization, e.g., Abbot Creek, were used as measures of the biotic potential for invasion to occur. We defined nine candidate logistic regression models that represented various combinations of these three factors and used an information-theoretic approach to evaluate the relative plausibility of competing models. Models combining local habitat (width) with landscape characteristics of mean summer temperature and number of road crossings in combination with the biotic variable distance to the source of hybridization were the most plausible models, yielding overall classification accuracies of about 88 percent. However, individual effects within these models could not be discerned because of collinearity. The presence of hybridization was positively associated with mean summer water temperature and number of upstream road crossings and negatively correlated with distance to the source of hybridization and stream width. Linear regression analyses showed that the distance to the source of hybridization was the only factor related to the proportion RBT admixture among hybridized sites. Finally, trout (> 75 mm) density was negatively related to stream width and elevation among the study streams. Our results suggest that hybridization increases in streams with warm water temperatures, high land use disturbance and close to the primary source of hybridization. Management strategies for preserving nonhybridized WCT populations should attempt to eradicate populations with high levels of RBT admixture in warmer streams with high densities of hybrid fish.

Yellowstone Cutthroat Restoration in Goose Creek

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Goose Creek is a tributary to the Stillwater River in Park County north of Cooke City, Montana. Goose Lake, located at the head of the creek, has recently become the wild brood source of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri;* YCT) for the Montana hatchery system. A small cascade that is not a complete barrier to fish passage has to date precluded brook trout (*Salvelinus fontinalis*) from colonizing Goose Lake. Brook trout dominate the creek downstream from this cascade. Three lakes are present on a tributary stream to Goose Creek and these lakes also harbor brook trout populations. There is approximately 6 mi of stream between the cascade barrier and the confluence with the Stillwater River. Near the confluence there is a series of three natural waterfalls that isolate Goose Creek from the rest of the drainage. In August of 2007, Goose Creek and the three lakes were treated with rotenone in the formulation CFT Legumine to remove brook trout The goal of the treatment was to prevent brook trout from colonizing Goose Lake and to expand the range of YCT in the drainage. Rotenone was applied at a rate between 1.5 and 3 parts/million (ppm) to the lakes and 1 ppm in the stream. Rotenone was applied to the lakes using an outboard powered boat and a trash pump system. Drip station and backpack sprayers were used to treat the stream and associated backwaters. A helicopter was use to transport equipment and personnel into and out of the site. The success of the project has yet to be determined. The area will be treated a second time in 2008 to insure a 100 percent kill of brook trout was accomplished.

Effects of Fish Size and Stream Characteristics on Piscicide Effectiveness

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The piscicides rotenone and antimycin are important tools in fisheries conservation but their application can be both inefficient and ineffective. Current information on the toxicity of these piscicides is based on a narrow size class of fish and persistence of toxicity is not known for a wide range of environmental conditions. For example, the toxicity of piscicides has been assessed in separate studies using juvenile and adult rainbow trout but has not been compared across a wide range of fish sizes. We determined the toxicity of rotenone and antimycin to a wide range of sizes rainbow trout (*Oncorhynchus mykiss*) and determined the applicability of piscicide persistence models over a wide range of environmental conditions. We tested the toxicity of rotenone (12.5 ug/L) and antimycin (7.5 ug/L) to rainbow trout from 31-345 mm total length. Rotenone killed fish faster than antimycin but no significant relationship existed between size of fish and time to death. We also developed models that measured the detoxification of piscicides caused by the interactive effects of combined stream characteristics. These models were tested against measurements of piscicide persistence in stream applications. The predictive ability of the models was good using reclassification procedures but varied when models were applied to data from stream applications. Models to predict the persistence of piscicides in streams will enhance the efficiency and effectiveness of piscicide applications.

Toxicity of Fintrol® (Antimycin) And Prenfish® (Rotenone) to Three Amphibian Species

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The toxicity of two piscicides, Fintrol® and Prenfish®, to Columbia spotted frogs (*Rana luteiventris*), long-toed salamanders (*Ambystoma macrodactylum*), and Rocky Mountain tailed frogs (*Ascaphus truei*) of varying life stages was determined from 96-h tests. The 96-h LC50 values for Fintrol ranged from 13.7 to 192 µg/L and for Prenfish the range was 0.009 to 9.65 mg/L. Tailed frog larvae were the most sensitive to both piscicides, surviving exposure to Fintrol as low as 3.7 µg/L, and having 10-percent mortality to the lowest test concentration of Prenfish tested (0.005 mg/L). Spotted frog adults survived exposure to Fintrol at concentrations six times the label prescription, and survived exposure to Prenfish up to 4.5 times the label prescription. Long toed salamander larvae survived exposure to Fintrol at levels ~ 30 percent higher than the label prescription, but had a similar sensitivity to Prenfish as some species of fish. Comparing the results of these tests with tests on fish and other amphibians showed that when used in the field, Fintrol would likely not have an impact on any of the species or life stages tested, and Prenfish would not likely impact adult amphibians but could have an impact on larvae.

Age Moderated Effects Of Fintrol® (Antimycin) on Larval Amphibians

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The use of piscicides to remove competing and hybridizing non-native fish has become a commonly considered option in conservation programs focused on preserving and restoring native salmonid fishes in the intermountain west. However, piscicide projects have been criticized, especially by opposed publics, as heavy handed, with unintended and harmful effects on non-target organisms – primarily aquatic macroinvertebrates and amphibians. Past experiments and field observation have generally shown field level dosages of Fintrol®, an antimycin based piscicide, to have relatively little effect on larval (tadpoles) and adult amphibians. In 2003, while conducting a piscicide treatment, we observed mortality of western toad (*Bufo borealis*) larvae in side-channel water that had been sprayed with Fintrol®. In 2004 *in situ* bioassays were conducted during a stream application of Fintrol® (10µg/L for 7-8 hrs) to determine the effect of treatment on amphibians. Adult, sub-adult, and larval Columbia spotted frogs (*Rana luteiventris*), as well as larval western toads, were placed in live cars in the treatment section. All spotted frog age-classes survived until release 48 hrs post-treatment; however, western toad larvae experienced 100-percent mortality. From 2005

to 2007 we conducted a series of laboratory experiments (water pH of 7.5-8.0 and 21 °C) with these two species to better determine if the mortality we observed in the field was specie age, or dosage related. Amphibian larvae were exposed to a series of Fintrol dosage (0-120 µg/L) at different stages of maturity in a total of 141 aquaria exposure trials. Mortality was high for both species at field level dosages (5-20 µg/L) at early post-egg larval stages (Gosner stage 22-24). Mortality decreased as larvae aged and by Gosner stages 29-30 both species seemed relatively resistant, at least as measured in terms of direct mortality, to moderate dosages of Fintrol®. After Gosner stage 30 very high dosages of Fintrol (60-80 µg/L) were required to cause mortalities > 50 percent. These results suggest that carefully timed Fintrol treatments might have minimal effects on at least these two species of amphibians. However, treatments conducted under different water quality conditions may lead to different results.

Pearl Dace in the Big Muddy Creek Watershed: Extirpation Saved by the Barrier

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During 2007, we reviewed Pearl Dace (*Margariscus margarita*) occurrence records and systematically resurveyed sites of current and previous occupation in the Big Muddy Creek watershed in NE Montana. Thirteen sites (4 main-stem Big Muddy and 9 tributary sites) were surveyed in June, and then re-sampled in September following Bramblett's prairie fish sampling protocols. Four of these locations had old museum pearl dace voucher records that had been resampled by MSU from 2000-2003, and are now confirmed absent. Northern pike captured in June surveys were vouchered; therefore the September survey could potentially document stream reach recolonization. Introductions of northern pike have been implicated in the decline of numerous local populations of native minnow species including the pearl dace. Our surveys collected 14 (9 native) prairie stream species. Pearl dace were only collected at one tributary stream site in the Big Muddy. Species that were closely associated with the pearl dace were fathead minnows, brook sticklebacks, northern redbelly dace and white suckers. Sites with northern pike present ($n = 4$) had significantly fewer fish species ($P = 0.0304$) than non-pike stream reaches ($n = 22$). Furthermore, samples from stream reaches with barriers from the mainstem Big Muddy ($n = 11$) had significantly more fish species ($P = 0.011$) and numbers of individuals ($P < 0.0001$) than sites without barriers ($n = 15$). Intact native prairie fish communities are becoming rarer to find. By documenting "non-pike" refuge areas or initiating pike removal projects, reintroductions of pearl dace may be considered as a management tool for the persistence of this species in the glaciated prairie streams of Montana.

Mate Choice and Reproductive Ecology in The Phoxinus Eos/ Phoxinus Eos-Neogaeus Complex

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The Northern Redbelly Dace (*Phoxinus eos*) and the Finescale Dace (*Phoxinus neogaeus*) can hybridize to form an all-female, gynogenetic (asexual) "species", *Phoxinus eos-neogaeus,* which requires sperm from one of the parental species to stimulate development of diploid, clonal ova. This hybrid occurs in Montana along with one of the parental species, *P. eos*. We investigated the reproductive ecology of this complex including mate choice in *P. eos* males and in the hybrid, and various clutch characteristics in both species. Mate choice experiments used a choice-tank with the "choosing" fish in a central section and one "choice" fish at either end behind clear, perforated dividers. Each trial was recorded from above for approximately 8 min, after which the fish at the ends were swapped, and the trial repeated. Results for each "chooser" fish thus consisted of the proportion of time spent in each third of the central section, for two combined trials. Clutch characteristics were determined by dissecting preserved females and counting, weighing and measuring appropriate enlarged oocytes or ova. Results indicated that male *P. eos* showed no preference for either the sexual *P. eos* females or the asexual *P. eos-neogaeus* hybrids. Further, though females of both types preferred larger males to smaller males, the strength of this preference did not differ between the two types of females. Finally, reproductive traits did not differ between the two types of females. We suggest that these results may be due to the incorporation of some sperm into the offspring of the hybrid females.

Yellowstone Lake Cutthroat Trout—Last Gasps of Life or Beginnings of Renewal: Will Non-Native Species Removal Efforts Aid Yellowstone Cutthroat Trout?

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Yellowstone Lake cutthroat trout (*Oncorhynchus clarkii*), an icon of western trout fishing and once the bright spot in a dim outlook for native cutthroat trout populations throughout the west, are seriously threatened by a nonnative lake trout population. Soon after discovery, Yellowstone National Park initiated an intensive gillnetting program aimed at suppressing lake trout numbers to levels that would allow cutthroat trout to sustain a healthy population. From 2001 to date we have removed almost 270,000 lake trout (*Salvelinus namaycush)* from the system. Despite this effort, lake trout in Yellowstone Lake are still present in high numbers and evidence suggests that the population is continuing to expand. A new spawning site was discovered in 2006; 2004 saw the highest number of mature lake trout removed from the lake to date; and increasing numbers of smaller, immature lake trout have been removed for the last six years. Suppression efforts are surely slowing the rate of expansion of lake trout in Yellowstone Lake, but will the program be able to decrease lake trout enough to provide adequate protection for native cutthroat trout? Recent increases in catch of cutthroat trout

juveniles throughout the lake are very encouraging. However, an upward trend in catch-per-unit-effort of lake trout by gillnets is cause for concern. In addition, and perhap even more serious is the three-fold increase in lake trout catch by anglers in 2007. In pa t year this statistic has been a good indicator of catch rates on the spawning grounds during the following year.

Spawning Demographics and Early Life History of Lacustrine-Adfluvial Bull Trout in Quartz Lake, Glacier National Park, Montana

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Habitat fragmentation and introduction of nonnative fishes, e.g., brook trout (*Salvelinus fontinalis*) and lake trout (*Salvelinus namaycush*), have resulted in substantial reductions in the native range of bull trout (*Salvelinus confluentus)*, contributing to the listing of Columbia River basin bull trout as threatened under the U.S. Endangerment Species Act in 1998. Therefore, recent invasion of lakes in Glacier National Park by nonnative lake trout is a major concern. Because lake trout were first captured in Quartz Lake in July 2005, we sought to document unique characteristics of the lacustrine-adfluvial bull trout population prior to changes associated with the lake trout invasion. Specifically, we are investigating spawning demographics and early life history of bull trout in Quartz Lake. Starting in August 2007, a 'picket fence' weir with trap boxes was positioned in Quartz Creek at the inlet of Quartz Lake to capture adult bull trout spawners ascending and descending Quartz Creek. Electrofishing was used to sample juvenile bull trout rearing in Quartz and Rainbow creeks. Redd counts were conducted in Quartz and Rainbow creeks during mid October. Physical habitat was assessed in both streams, and temperature loggers were placed throughout the stream network. A gauge was installed near the mouth of Quartz Creek to monitor flow. Analyses will focus on effects of physical habitat characteristics on the distribution and abundance of bull trout in tributaries to the lake. The resulting information will provide a reference for future remediation in Quartz Lake and other bull trout refugia in Glacier National Park.

Piscicide Drip Station Placement Efficiency

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Eradication of nonnative fish using piscicides is a common restoration and conservation tool for native salmonids in the state of Montana. Piscicide drip stations are commonly placed at locations that are most convenient for access by the piscicide applicator. Little guidance exists on the most effective drip station placement in different channel types, e.g., straight, meander, and riffle, and within a stream cross-section, i.e., edge and center. Placement may affect mixing distance and therefore application efficiency. We compared mixing distance between locations in a channel cross-section and among different channel types. Because

direct measurement of piscicide concentration in the field is impossible, sodium chloride (salt, NaCl) was used as a tracer. NaCl solution was applied at the center or the edge of three channel types. Conductivity was measured at stream cross sections downstream from the application site at 10 regularly spaced intervals. Measurements formed a grid that identified the plume of the simulated piscicide and its mixing rate. The simulated piscicide was considered evenly mixed through the stream when the variation among measurements within a cross-section was < 1 percent. ANOVA was used to compare mixing distances between application location and among channel types. Significant differences existed in mixing distances between edge and center applications when variation in discharge volume was accounted for. Piscicides should be applied to the center of a stream channel to minimize mixing distance.

The Effect of Flow Regulation on Snake River Cutthroat Trout: Potential Consequences of Alternate Flow Regimes on the Behavior and Survival of Three Life-Stages

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An undisturbed river network is characterized by numerous channel processes and structures that act as behavioral cues or habitat for organisms. In response to this environmental variability, organisms evolve adaptations which allow them to persist. When river systems are altered, e.g., dammed, organisms (or life-stages of organisms) may not be adapted or able to respond to the novel environmental conditions, and the range of adaptations, e.g., life-history types, expressed by organisms may be constrained. Snake River cutthroat trout (*Oncorhynchus clarkii bouvieri*) have persisted in the Snake River through a century of flow regulation. However, it is unknown to what degree flow regulation has reduced the variability of cutthroat trout adaptations or influenced survival. As a first step in exploring how a disturbed environment affects the expression of Snake River cutthroat trout adaptations, we developed a conceptual framework of how life-stage specific survival might relate to flow regulation at Jackson Lake Dam on the Snake River. This conceptual framework will structure future research on the range of adaptations currently expressed by Snake River cutthroat trout and the implication of adaptation loss on the potential for Snake River cutthroat trout to respond to future disturbances.

Biological Sciences – Terristrial

The following Abstracts are from presentations made at a Joint Meeting of the Montana Chapter of the Wildlife Society, The Society for Northwestern Vertebrate Biology and Partners for Amphibians and Reptile Conservation

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Brucellosis Surveillance in Free-Ranging Montana Elk — Surveillance Challenges and ReSults

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Montana Fish, Wildlife and Parks has conducted surveillance for brucellosis in elk (*Cervus elaphus*) since the early 1980s. Occurrence of brucellosis in a domestic cattle herd in Montana has raised a concern producers have about potentially infected elk transmitting the disease to cattle. Recent events have increased the challenges of obtaining adequate samples and interpreting standard serologic tests. Based on historic records brucellosis in free-ranging elk has only been documented within the Greater Yellowstone Area with a sero-prevalence of < 4 percent. Sero-prevalence seemingly has not changed greatly over time, but new confounding factors are influencing surveillance activities. A brief history of surveillance efforts, new challenges faced in conducting surveillance and interpreting serologic test results and recent survey findings were presented.

CWD Surveillance in Montana

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Chronic Wasting Disease (CWD) is a fatal neurological disease of cervids. Montana Fish, Wildlife and Parks has conducted surveillance for CWD since 1998. During 2007-2008, surveillance was conducted in the eastern portion of Montana near the borders of Wyoming and Canada where CWD has been detected in free-ranging deer and elk. Samples from over 1450 deer, elk and moose were collected and tested. The prion associated with CWD was not detected among samples collected. Samples consisted primarily of hunter-harvested animals (n = 1381), road kills (n = 81) and symptomatic animals (n = 15). A total of 177 elk (*Cervus elaphus*), 1060 mule deer (*Odocoileus hemionus*), 239 white-tailed deer (*O. virginianus*) and one moose (*Alces alces*) have been tested. A total of 11,777 deer, elk and moose have been tested since 1998 with no evidence of CWD in Montana's free-ranging populations. Montana has also adopted a management plan should CWD be detected in wild cervids. The recommended alternative presented in the record of decision was discussed.

Northwest Gap Analysis Project: Innovative Approaches to Species Distribution Modeling for Local and Regional Species Conservation

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Accurately representing species occurrences across large landscapes is vital for species conservation at local and regional scales. Previously, spatial and thematic resolutions at which Gap species modeling was conducted have been too coarse to optimally inform local conservation. Primarily this is because species modeling needs to be consistent across large regions, which require coarser, region-wide environmental data. We attempt to address this mismatch of resolutions by modeling species' range, distribution, and habitat quality as distinct products. Range models express species' spatial arrangement at coarse resolutions using 10-digit hydrological units as map units. Species' distributions were modeled as functions of regionally-mappable environmental variables but also of select fine-resolution variables not available as region-wide layers. Habitat quality models highlighted portions of region-wide distributions determined, via expert input, to support high or low rates of reproduction and survival, and thus present more detailed thematic information. Our approach is being applied to ~ 650 Northwestern terrestrial vertebrates and relies on both deductive and inductive modeling approaches. A web-based expert review system has been developed to obtain invaluable knowledge about species habitat preferences, historical and current range expansion or contraction, and important environmental variables. We believe our approach will make Gap species distribution modeling in the Northwest more applicable to local and regional conservation goals.

Wolf Kill Rates: Predictably Variable?

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Abundance and diversity of the prey assemblage affects ability of predators to successfully capture and kill prey; such variation is a fundamental driver of ecosystem dynamics because per-capita consumption rate strongly influences stability and strength of community interactions. Descriptions of predatory behavior in this context typically include the functional response, specifically the kill rate of a predator as a function of prey density. Thus, a major objective in studying predator-prey interactions is to evaluate the strength of numerous factors related to kill rate of a predator, and subsequently determine forms of its functional response in natural systems because different forms have different consequences for ecosystem dynamics. Recent controversies over the nature of predation focus on respective roles of prey and predator abundance in affecting a functional response. However, resolution requires more direct measures of kill rates in natural systems. We estimated wolf (*Canis lupus*) kill rates in a tractable and newly established wolf-elk (*Cervus elaphus*) bison (*Bison bison*) system in the Madison headwaters area of Yellowstone National Park during winters 1998-1999 to 2006-2007 to document the transition from over seven decades without wolves

to a well-established top predator population. Wolf abundance, distribution, and prey selection varied during the study concurrent with variations in demography, distribution, and behavior of elk and bison. These dynamics enabled us to evaluate factors influencing variations in wolf kill rates and the forms of their functional response.

Citizen Science for Monitoring Common Loons in Glacier National Park

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Glacier National Park harbors approximately 20 percent of Montana's breeding common loons (*Gavia immer*), a Montana Species of Special Concern, with an average of 45 adults and five chicks each year. Surveys of Glacier's loon population have been conducted annually since 1988, but limited resources have restricted data collection to a one-day event known as Loon Day. In 2005, the Citizen Science Project for Common Loons was created to gain a better estimate of population health and to begin to identify factors affecting l on nesting success. Since that time, we have recruited and trained nearly 300 volunteers to monitor lakes with loons repeatedly throughout the nesting season. These volunteers conducted more than 1000 surveys of 45 priority lakes, which resulted in a robust estimate of loon population health. The large data set has also given us valuable information about Glacier's loons, uch as chick hatch dates, migration dates, chick mortality, and chick detectability that would have been missed by monitoring only on Loon Day. Volunteers also helped us locate and map nest sites, areas of potential disturbance, and probable nursery areas on each of the lakes with known nesting activity for use in future monitoring and management. Challenges to using the Citizen Science model for this project include investing a substantial amount of effort to find, train and manage volunteers and to maintain data quality. The rewards include educating volunteers in depth about a resource issue, fostering stewardship, and increasing the quantity and quality of data.

Habitat Comparisons of Historically Stable and Less Stable Bighorn Sheep Populations

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Management of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) focuses on 1) population demographics, 2) immunological state, and 3) habitat characteristics. Demographic targets have been identified for successful populations. Habitats suitable for bighorn sheep have also been identified, and bighorn sheep population response to immunological stressors has been documented. Research has identified domestic sheep (*Ovis aries*) as a potential source of pneumophilic bacteria to bighorn sheep although not all bighorn die-offs are attributed to such contact. Limited research has documented how habitat differences between stable and less stable bighorn populations influence their success. Understanding these habitat differences may help explain how habitat contributes to bighorn

population stability. This study attempts to evaluate differences in spatial, vegetative, and geographic habitat characteristics of summer and winter ranges between historically stable and less stable bighorn sheep populations that occupy rangeland and open forest habitats in Montana in the presence of domestic sheep. Habitat variables will be evaluated for two summers on summer and winter ranges of two bighorn sheep populations in Montana in both their entire seasonal ranges and areas identified as foraging habitat. Land cover, slope, aspect, elevation, solar radiation index, and distance to escape terrain will be quantified in each habitat using a Geographic Information System (GIS). Field sampling will determine shrub canopy cover, frequency of graminoids and forbs, and horizontal visibility of each habitat. Habitat characteristics of historically stable and less stable populations will be compared. Preliminary results were presented.

A Comparison of Non-Invasive Genetic and Traditional Approaches to Estimating Animal Abundance

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Non-invasive genetic population estimation, in which capture-mark-recapture (CMR) statistics are applied to individual genotypes obtained from hair or fecal samples, has gained interest among wildlife managers and researchers as a promising alternative to traditional live-trapping methods when working with rare and elusive species. This study explored another potential advantage of non-invasive genetic population estimation—surveying relatively common and trappable species occurring in difficult-to-access areas. We evaluated efficacy of non-invasive genetic sampling for CMR estimation of snowshoe hare (*Lepus americanus*) densities in the remote backcountry of Glacier National Park, Montana. We tested various combinations of pellet collection methods, plot numbers and sizes, sampling duration, and baits to maximize sample sizes (number of pellets collected for genotyping) and minimize time, labor, and costs in the field. At five study sites in Glacier National Park, we estimated hare abundance using this optimized non-invasive genetic approach as well as traditional live-trapping and pellet index methods. We present findings from this field study and a simulation-based cost-benefit analysis of abundance estimation using traditional live-trapping vs. non-invasive pellet sampling.

Spatial and Temporal Relationships of Adult Male Black Bears to Roads in Northwest Montana, 2003-2004

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Roads have direct and indirect consequences for wildlife. Vehicle collisions are a direct cost of roads on wildlife. Indirectly, roads may increase mortality of game species by

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increasing hunting pressure along these roads. Little is known about how roads affect hunting vulnerability of black bears (*Ursus americanus*), especially adult males. Adult males are the most desirable age and sex class to many hunters, which could lead to over-harvest of this sex and age class. I hypothesized that adult male black bears will avoid roads during spring and fall hunting seasons compared to summer; so road use, and therefore hunting vulnerability, should decrease during hunting times. I used a sample of six GPS-collared adult male black bears and ANCOVA methods to evaluate whether these bears avoided roads between seasons. This study illustrates the importance of season in determining how bears use roads. My results showed that road metrics proximate to bears decreased from nonhunting to hunting seasons. Adult male black bears were less likely to be near open roads during legal hunting seasons, which may reduce bear vulnerability during the fall hunt. This is consistent with the idea that bears survive to maturity by avoiding roads thus avoiding hunting and traffic; however other possible explanations exist. Especially in the roaded area, elevation and roads were confounded, making it difficult to tease apart individual effects. Thus, interpretations of bear avoidance of roads should be treated with caution, as bear responses to roads may also be a response to elevation.

Ongoing Surveying for Flammulated Owls in Montana Via Citizen Scientists and Technicians

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Flammulated owl (*Otus flammeolus*) populations in the Intermountain West may be declining due to habitat alterations, yet their secretive nature and scattered distribution have made monitoring difficult. In 2005 the Avian Science Center (ASC) and the Northern Region of the USDA Forest Service (USFS) initiated the first-ever Region-wide survey for flammulated owls in lower elevation, dry forest types of Montana and northern Idaho. Sampling methods using GIS modeling proved effective, and we now have a clearer understanding of owl distributions both east and west of the Divide. However, a long-term monitoring program using an established protocol is needed to understand habitat associations and population trends. A citizen-science approach has potential to provide a cost-effective means of collecting population data across a large area over time, and flammulated owl surveys are particularly appropriate for citizen monitoring because identification is straight forward, equipment is simple and inexpensive, and the public has a keen interest in both hearing owls and contributing to valuable science. In 2007 we initiated a successful pilot project with the help of volunteers from local Audubon groups who "adopted" survey route we plan to expand this monitoring in 2008. I will highlight the successes and challenges of a citizen science approach and discuss how our future surveys will draw on strengths of this approach together with a program using paid USFS technicians. Ultimately our goal is to better assess the habitat association of these owls particularly in the wildland urban interface.

Habituation, Hunting, and Recreation: Understanding Human Influences on Elk Behavior on the Wildland-Urban Interface

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Elk (*Cervus elaphus*) are increasing in many areas throughout the west, especially in the wildland-urban interface (WUI). Wildlife managers are unable to use traditional public hunting to manage these elk given the resistance WUI homeowners to hunting near their homes. As an example of this problem, the intrinsic growth rate of the North Hills Elk Herd in Missoula has been ~11 percent since the early 1980s, and the herd now numbers over 300 animals. North Hills' landownership is a complex matrix of public and private lands that range from partial to complete exclusion of hunting; thus, elk harvest is low and provides little population-level regulatory ability. Little research has been done assessing either the effects of hunting on elk distribution or the specific effects that hunting has on elk and human avoidance in the WUI. We used resource selection functions (RSF) based on GPS-collared adult female elk during the fall 2007 hunting season to test the effects of hunting on elk resource selection and avoidance behaviors in the WUI. Preliminary RSF results suggest that elk avoided areas of human use only during hunting season. Building on this work, a series of approach trails will be implemented to determine the degree of avoidance of humans by elk for hunted and non-hunted populations. This knowledge will allow managers to better understand the degree of hunting necessary to reduce elk habituation while providing needed information on the efficacy of current hunting seasons for managing WUI elk populations.

The Effect of Global Climate Change on a Snow Dependent Species: a Case for the Wolverine

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Wolverine (*Gulo gulo*) show a circumpolar arctic distribution with southern peninsular extensions occurring in mountainous regions of orth America and Eurasia. It has been hypothesized that wolverines require snow for reproductive denning. If wolverines are associated with a climatic zone associated with persistent snow during the denning season (Feb-May), they could be adversely affected by global warming. To investigate the association of wolverine reproductive denning to the presence of persistent spring snow, we overlaid all documented wolverine den sites on a MODIS-based snow coverage for the period 24 April to 21 May, from 2000 through 2006. Of the 631 dens, all but six occurred in pixels which were typed as snow throughout the period in at least 1 of 7 yrs. Additionally, we found that year-around habitat use was also constrained to these same areas. In 6 radio telemetry studies in the western U. S., over 90 percent of year-around relocations occurred within areas associated with persistent spring snow. Coupled with recent analyses of historical occurrence and genetic studies (see Schwartz et al), these data provide strong evidence that wolverines are confined to a narrow and easily defined climatic niche.

Status of Spotted Knapweed Invasions in Wildlife Habitat

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Spotted knapweed (*Centaurea stoebe micranthos*) is a widespread noxious weed in the western U.S. and Canada. Spotted knapweed can be controlled using herbicides, mowing, grazing, cultivation, and biological control (natural insect enemies introduced from the native range of the plant). We are beginning to see reduction of knapweed density in rangeland wildlife habitat, which we can attribute at least in part to biological control insects. Some recent findings are summarized. The root weevil (*Cyphocleonus achates*) kills knapweed plants and reduces thriftiness of surviving plants. At two sites where *C. achates* was released and weevil populations and knapweed density subsequently measured, dramatic increases in weevil populations were followed by equally dramatic declines of knapweed density (77 and 99% decline after 11 yrs). In field releases of *C. achates* that incorporated control plots, declining biomass of knapweed could be attributed to effects of weevil attack within 4 years of their release. Knapweed density was also impacted by flooding, drought, and grazing by white-tailed deer. Although drought reduces survival and vigor in knapweed plants, *C. achates* effects are demonstrable and additive. Finally, larval development of some biological control agents, and evidence of accelerated development over the last 7 yrs were discussed.

Climate Change Impacts to Amphibians and Reptiles

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Amphibians and reptiles may show greater responses to climate change than will other terrestrial vertebrates because, as ectotherms, life history, particularly reproduction, growth, and development, are directly affected by temperature. All species will be faced with indirect effects of climate change, such as changes in habitat due to changing hydrology or vegetation, but herpetofauna are less vagile than birds and mammals and will be less able to shift their distributions to match changing climates. For amphibians, effects that have been documented often involve changes in phenology. The timing of snowmelt is the primary influence on when montane amphibians breed. In the northern Rocky Mountains and the Pacific Northwest, amphibians are likely breeding earlier than in 1950. Climate models predict reduced extent and duration of future snow packs and increasing summer temperatures, which may alter the hydrology of the small wetlands that most species require for breeding. Increasing temperature has been hypothesized to facilitate the spread of a pathogenic fungus into some populations of tropical frogs. The relevance to Montana's amphibians is uncertain. For reptiles, particularly those with temperature-dependent sex determination, increasing temperatures may have large demographic effects. Specific predictions about effects of climate change are difficult and reflect the complexity of the issue. Montana herpetofauna occur mostly at the extremes of their climate envelopes, and some species may benefit from climate change.

Sustaining Wildlife Populations in the Madison Valley, Montana, in the Face of Subdivision Development and Human Population Growth

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A Madison Valley Wildlife Overlay district was developed for the Madison Valley to help ensure that new development in the Valley protects the wildlife resource by identifying areas critical for wildlife and developing guidelines and requirements for development within these areas. This is a needed planning tool throughout the Intermountain West. In most counties wildlife habitat is given little consideration and is usually input into the planning process after many crucial decisions have already been made. Little consideration is given how development will impact neighboring properties or fit into a larger planning area. The Overlay district is based upon *A Wildlife Conservation Assessment of the Madison Valley, Montana* by the Wildlife Conservation Society, the Craighead Environmental Research Institute, and the Madison Valley Ranchlands Group. The assessment was based on analysis of 15 focal species. Priority areas derived from the Assessment were divided into four categories: Wildlife diversity habitat areas, Wildlife habitat connectivity areas, Riparian willow/cottonwood habitat areas, and Riparian corridors. The first phase of the project identified and mapped the most critical areas in the valley for wildlife habitat. General consensus was reached with area biologists and results were discussed and refined with other stakeholders. The second phase will develop specific guidelines for proposed development within the conservation overlay for various habitat quality 'zones' that maintain wildlife value of the area. A final proposal, maps, and development guidelines will then be presented to the County Commissioners for approval.

The Trivers-Willard Model and Southwestern Montana Elk

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The Trivers-Willard (1973) model (TWM) suggests maternal control of offspring sex (*in utero* or by the end of parental investment) may be an adaptive advantage in some species. In sexually dimorphic, polygynous ungulates, the TWM suggests male offspring should be favored when the female is in superior condition. Population and harvest models for elk (*Cervus elaphus*) often assume sex ratios of 50:50 at parturition and recruitment. We tested this assumption using 11,094 known-sex fetal elk and 4404 known-sex calf elk (age 6-8 mos) from hunter harvest in three herds in southwestern Montana (1961-2007). We included maternal, individual, and environmental condition covariates to test the TWM *in utero* and near recruitment. After 30 logistic regression and chi-square te ts on fetal sex ratios using data from three populations, five distinct time periods, and 11 variables, we found significance in three tests ($P \leq 0.05$); two supporting the TWM, and one opposing it, suggesting little evidence to support maternal control of fetal sex. However, all populations

tested demonstrated a significant female-biased ratio of calves at harvest (60:40; $P \leq 0.003$). We concluded that differential mortality of males must occur between the first trimester *in utero* and age 6-8 months. However, due to inconsistent evidence from six elk calf mortality studies across Montana, Wyoming and Idaho, further research is necessary to determine when and how sex ratios become biased. We suggest that elk population managers take into account potential differences in sex ratio at recruitment when building population and harvest models.

Influence of Nutrient Acquisition and Habitat Selection on Breeding Propensity of Female Lesser Scaup on Lower Red Rock Lake, Red Rock Lakes National Wildlife Refuge

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North American lesser scaup (*Aythya affinis*) populations have been declining for nearly 3 decades. Evidence suggests that female lesser scaup are arriving at breeding areas in poorer body condition then historically, leading to reduced female breeding propensity. We undertook the current study to investigate relationships among nutrient allocation and acquisition strategies, pre-breeding habitat selection, and breeding propensity of adult female lesser scaup. During summer 2007, we conducted the first year of data collection for this 3-yr study. We captured 30 female lesser scaup on Lower Red Rock Lake, Red Rock Lakes NWR in mid-May, marked them with radio transmitters, and followed them intensively through the breeding season. Extreme drought conditions persisted throughout the field season. One radio-marked female mortality occurred in May, 12 females emigrated prior to mean nest initiation, i.e., 21 Jun, 17 remained throughout the egg laying period, and 13 remained until tracking ended in late August. We found six nests from 17 females that remained throughout the egg-laying period. Home-range habitat attributes of pre-breeding females investigated include average water depth, number and size of ponds, percent open water, total open water/emergent vegetation edge, and number of islands within the core area. Female body tissues (blood and claw), local forage items, and an egg from successful breeders were collected for stable isotope analysis to assess nutrient strategies likely affecting breeding propensity. Preliminary analysis is underway and results of those analyses were presented. Our goal is to gain insights into important life history strategies that limit reproduction in female lesser scaup.

Blood-Lead Levels of Fall Migrant Golden Eagle in West-Central Montana

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Lead has long been documented as a serious environmental hazard to eagles and other predatory, opportunistic and scavenging avian species. Due to lead poisoning in the bald eagle (*Haliaeetus leucocephalus*) and the golden eagle (*Aquila chrysaetos*), the use of lead shot for waterfowl hunting on federal and state lands was banned in 1991. At that time, this was thought to be the only major source of the lead exposure. More recently, lead poisoning from ingested lead-bullet fragments and shotgun pellets has been identified as the leading cause of death in California condors (*Gymnogyps californianus*), leading to the recent ban of lead ammunition within the "California Condor Recovery Zone." Another on-going study on common ravens (*Corvus corax*) and Bald Eagles in Wyoming has shown a direct correlation between very high blood-lead levels and the onset of rifle hunting season. Indeed, overwhelming evidence shows that lead toxicity is still prevalent in the environment, and mounting data points to fragmented rifle bullets as the source. We sampled blood from 39 Golden Eagles during fall 2006 and 2007 to quantify a suite of heavy metal contaminants with emphasis on lead. We performed a simple field test on 18 eagles and found eight to contain elevated blood-lead levels. All 39 samples were lab analyzed, and full results of this analysis were presented.

Understanding Climate Change Interpretation

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Climate change has been in the news recently with impacts projected to vary from little change to catastrophic. To adequately understand what is being presented, one needs to understand how the data is being interpreted and in some cases "spun." Examples of how earlier records are ignored, data is interpreted, and the same data can be interpreted differently was presented with numerous examples. Examples will consist mostly of Montana data. The main emphasis will be on weather records, mountain snow pack, fires, and stream flow. Long-term records will be compared to short term records that are currently being used to advance the impact of climate change. Words such as "if," "when," "current trends," and "should" are being interpreted as "will," "inevitable," or "absolute" by many ob ervers. ometimes, changes that are reported to be caused by climate change result from other factors. In some cases, natural variability is interpreted to imply climate change. By understanding how the data is collected, modified, and reported, individuals will be better able to evaluate how climate change might impact their operations, or how it might influence their interpretation of field data or natural processes.

Strong Substructure of Greater Yellowstone Area Bison Revealed by Mitochondrial DNA from Amplified Fecal Samples

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Bison (*Bison bison*) in the Greater Yellowstone Area (GYA) congregate in distinct geographic areas during the rut. We hypothesized that fidelity to breeding areas would result in genetic differences among GYA breeding groups. We analyzed fecal samples from 120 bison in five breeding groups during the ruts of 2005 and 2006. Sequencing and restriction fragment length polymorphism analysis of a 470 bp segment of the mtDNA control region revealed significant differentiation between bison in Yellowstone National Park (YNP) and Grand Teton National Park ($F_{ST} = 0.236$, $P < 0.001$). We found even greater differentiation within YNP between the Lamar Valley and Hayden Valley breeding groups ($F_{ST} = 0.505$, $P < 0.001$), which are <50 km apart. This fine-scale genetic differentiation among breeding groups within YNP suggested strong female philopatry to natal ranges. These findings also suggested that these breeding groups should be considered separate management units with respect to conservation of current levels of genetic diversity. However, examination of nuclear loci is necessary to assess male mediated gene flow and better understand population structure of GYA bison. Decision-makers should consider genetic monitoring in the future to determine which breeding group winter migrants have emigrated from when taking actions to resolve brucellosis risk management priorities at park boundaries. The probability of conserving current levels of genetic diversity under various management scenarios should be evaluated as well.

Monitoring Common Loons in Glacier National Park

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The common loon (*Gavia immer*) has been documented from Glacier National Park since at least the early 20th Century. Sporadic observations were recorded until 1986 when the Montana Loon Day Survey was initiated. Efforts by park employees and volunteers increased during the 1990s; number of lakes surveyed on Loon Day increased from 31 to 50, the number of lakes with loons varied between 13 and 19, the number of adults varied between 26 and 48, and the number of chicks detected varied between 2 and 14. Mean chick production for the park during 1989-2004 was ~ 5/yr. Some lakes, particularly in the northeast part of the park, appeared to decline in loon productivity, although others on the west side exhibited increased chick production. However, prior to the advent of the Citizen Science Loon Project in 2005, variability in annual survey effort, inconsistencies in the abilities, dedication, and dependability of volunteers, and the limited time devoted to sampling loons in the park together cast doubt on survey results and reliability of trends. Lack of adequate staff and funding to coordinate loon surveys precluded intensive educational efforts, confirmation of questionable observations, clarification of ambiguous information, or maintenance of long-term data bases. Non-biologist volunteers have been a powerful force in some wildlife survey efforts, but coordinating and supporting such endeavors can be very labor and time-intensive. Because Glacier NP is host to ~ 20 percent of Montana's breeding Common Loons, a state species of special concern, improving reliability of park

estimates of status and trend are necessary to ensure per istence of this specie . A itizen cien e approach is one way to help achieve that goal.

Predicting the Impacts of Land-Use Policies on Habitat for Amphibians Across a Privately-Owned Landscape in Northern Idaho

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Predicting impacts of landscape change on wildlife population i e sential for designing strategies to ensure persistence of species in a changing environment. We surveyed for presence of pond-breeding amphibian larvae at 105 randomly-selected wetlands in rural northern Idaho. We compared algorithmic (random forest) and information theoretic approaches to modeling breeding habitat for olumbia spotted frog (*Rana luteiventris*), Pacific treefrogs (*Pseudacris regilla*), and long-toed alamanders (*Ambystoma macrodactylum*) using these data. The information theoretic approach indicated that all three species were negatively associated with presence of fish, while the algorithmic approach indicated that fish were an important predictor of occurrence for Pacific treefro s and long-toed salamanders and that soil type was an important predictor for all specie . The best models from the information theoretic approach indicated that long-toed salamanders were positively associated with wetlands in forests and grasslands and negatively associated with agriculture, while Pacific treefrogs were positively associated with wetlands in agriculture and low-density forests and negatively associated with development. Both algorithmic and information theoretic models found that solar insulation was strongly associated with Columbia spotted frog presence. We used these models in conjunction with sets of stochastically predicted landscapes based on landowner surveys to predict the impact of land-use policies on amphibian breeding habitat. Policies that encouraged forest thinning and transitioning land from agriculture to grassland resulted in increased habitat for long-toed salamanders and Columbia spotted frogs. Concentrating future development around existing towns resulted in reduced breeding habitat for all three species.

Landscape Analysis of Baling Twine in Osprey Nests

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Baling twine is polypropylene rope used by farmers to tie together bales of hay. After the hay is used to feed livestock, loose strands of baling twine are sometime left in fields. ospreys (*Pandion haliaetus*) have a propensity to collect baling twine and use it to line their

nests. For example, one osprey nest near Missoula, Montana contained > ¼ mile of baling twine. Chicks and adults can easily become entangled in baling twine causing significant mortality: some studies estimate that over 10 percent of osprey chicks become so tangled that they die in the nests before fledging. Our goal was to describe the general extent of this problem. We sampled 115 osprey nests in parts of western Montana, Wyoming, Idaho and Washington. To test what landscape features are associated with the amount of baling twine in Osprey nests we used GIS analyses to describe land use within several different distances of nests. Not surprisingly, nests that are far (≥ 3 km) from any agricultural land tend to have no baling twine. However, the amount of agricultural land and livestock pastures within 1 km of osprey nests are poor predictors of the amount of baling twine in nests. These analyses suggest that Ospreys travel considerable distance to collect baling twine, and that fairly distant point sources of baling twine, e.g., a single, small dirty field, can be important. Our initial efforts in public education about the importance of picking up baling twine are promising.

Winter Survival and Habitat Selection by Female Greater Sage Grouse in South Phillips County, Montana

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Populations of greater sage grouse (*Centrocercus urophasianus*) have been seriously declining throughout their range. Most research has focused on demography, survivorship, habitat selection, and reproductive success during spring and summer. In contrast, there have been fewer ecological studies of survival and habitat and food selection during winter. We focused on over-winter survival and habitat selection of female sage grouse in South Phillips County, an area where greater sage grouse still occur in relatively high densities. We tested the long-held assumption that overwinter mortality of juvenile and yearling birds is about twice that of adult females. We followed 159 radio-marked juvenile, yearling, and adult females during the 2005 and 2006 winters. During these two winters all cohorts survived better than most published accounts (~ 90% survivorship) with juvenile and yearling hens surviving as well as adult hens. Greater sage grouse are sagebrush specialists during winter, subsisting almost entirely on a diet of *Artemisia* species. This narrow diet presents some physiological challenges, since sage leaves are generally difficult to digest and contain many secondary defensive compounds such as monoterpenes, sesquiterpene lactones, coumarins, and flavonoids. During winter, sage grouse in our study tended to select winter feeding sites that were relatively flat, and selected sage plants that contained higher crude protein levels than available across the landscape. We discussed general implications of our results for management and conservation of sage grouse.

Spatial Responses and Foraging Dynamics of Elk in Relation to Winter Wolf Predation Risk in Yellowstone National Park

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In the absence of an effective predator, food acquisition and energy conservation during winter largely influence spatial patterns of large herbivores in northern temperate regions. Resources are scarce and the energetic cost of movement is high; as a result animals would be expected to minimize movement to avoid unnecessary energetic costs. When a top predator is added to the system, such a strategy may not be compatible with avoiding predation risk, animals may increase their movement to avoid detection or facilitate escape. While avoiding predation, large herbivores must also balance conflicting demands of satisfying physiological needs. To evaluate spatial responses and foraging dynamics of elk (*Cervus elaphus*), with and without wolves (*Canis lupus*), we conducted an intensive telemetry-based study of the Madison-Firehole elk herd during 1991-2007. This occurred prior to significant wolf reestablishment (1991-1997), and when wolves had an established presence in the study system from 1998 through 2007. Prior to wolf-reintroduction, we randomly collected ~ 6000 elk locations, representing 5000 elk groups and 1900 independent behavioral observations (~ 950 hrs of observation time). Our data were complimented by > 5000 elk locations, representing 3500 elk groups, and 1850 independent behavioral observations (~ 925 hrs) after the reintroduction of wolves. We observed modest changes in home range size and reduced site fidelity as elk adjusted to presence of wolves, and some long distance dispersal away from core wolf use sites. Foraging behavior remained relatively stable with and without presence of wolves.

Keeping Common Species Common: What Does the Future Hold for Western Painted Turtles In The Mission Valley, Montana?

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Understanding population dynamics at the local and metapopulation level is critical for long-term conservation of wildlife. Survival and movement patterns provide valuable information for making management decisions in the face of environmental changes. I used capture-mark-recapture methods to estimate apparent survival rates and movement probabilities of adult and juvenile western painted turtles (*Chrysemys picta bellii*) across space and time in northwestern Montana. I also conducted road mortality surveys to examine the potential impacts of road mortality on the overall population size and structure. Five pond complexes were sampled three times a year from fall 2002 to spring 2005. I captured 1072 individual adults 5050 times and 442 individual juveniles 3078 times. Although both juvenile and adult apparent survival rates were influenced by pond, seasons, and year, I found very different patterns, spatially and seasonally, between age classes. Movement rates were

very low (< 4 %) and were influenced by distance between ponds and depth of originating pond. Road mortality averaged 185 individuals/year. Annual road mortalities ranged widely depending on pond characteristics but in general were higher than the 2-3 percent mortality suggested by other research to likely affect long-term viability in turtle populations. Population growth rate was negatively influenced by the presence of roads and positively influenced by movements. These survival and movement patterns illuminate the importance of maintaining habitat connectivity for long-term population viability. This population will be discussed in relation to the planned Highway 93 reconstruction project and the potential for climate change to alter wetland habitats.

Common Loon Movements over the Past 28 Months

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Each year hundreds of common loons (*Gavia immer*) stage on Flathead Lake during their fall migration. Banding data has provided information on winter locations and a few stop locations in between. Documenting the timing, route, duration and destinations are goals of this project. In October 2005 four adults were captured and surgically implanted with intra-abdominal Argos PTT-100 satellite transmitters (Microwave Telemetry, Inc.). Modifications of each PTT included doubling the battery capacity and fusing attachment materials to the exterior (final weight 65 g). Transmitter duty cycles were eight hrs on and 26 hrs off during the first six weeks to intensely monitor migration timing. Along with the PTTs, each bird was banded with USFWS and color bands. Updated information on loon movements was made accessible by using Satellite Tracking and Analysis Tool (STAT). Upon release each individual occupied separate locations of Flathead Lake. While one loon departed within the first week after surgery, three individuals remained on Flathead Lake until early November. Two general routes have led to four separate winter locations. Three individuals returned north along the eastern route to breeding areas in Alberta and Saskatchewan, Canada. Only one transmitter remained active since the fall/winter 2006-2007 to migrate along the same route as the earlier fall two more seasons. The distance between breeding and winter locations ranged from 2300 and 3535 km for each of the loons.

Estimating Territory Occupancy, Colonization Rates, and Extinction Rates for Common Loons in Northwest Montana

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Our research was designed to investigate the key biotic and abiotic factors influencing loon presence and identify, in addition to breeding lakes, other lakes that are important to common loons (*Gavia immer*) in northwest Montana. Specifically, we investigated the relationships between habitat characteristics, disturbance, and intraspecific interactions, and how they may be related to territory occupancy. Landscape scale intraspecific covariates

were the mo t important factors influencing occupancy while colonization and extinction rates remained constant. Models with habitat covariates and disturbance covariate ranked low. These results suggest that colonization and extinction rates are in a state of equilibrium, i.e., if an occupied territory is lost an unoccupied territory becomes occupied. Re ult al o support that while habitat and disturbance characteristics may have considerable influence on nest success and chick survival, they have little influence on territory occupancy. Prior to any management action, managers should evaluate the potential effects a ociated with increasing the probability of an unoccupied territory becoming occupied as increasing the number of occupied territories may not only have a positive effect on nest success and chick urvival, but at some threshold may also have a negative effect.

The Potential Effect of Energy Development on Ungulates in Eastern Montana: A Literature Review

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Energy development is arguably one of the biggest threats to wildlife conservation in eastern Montana. Drawing on the published and gray literature, we review the effects of energy development throughout similar habitats present in ea tern Montana throughout Alberta, Montana, Idaho, Wyoming, Colorado, and elsewhere in the Rocky Mountain west on ungulates including mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), bighorn sheep (*Ovis canadensis canadensis*), and pronghorn antelope (*Antilocapra americana*) We summarized effects of different kinds of energy development (treatments), different study designs (from weaker to stronger inference; observational, comparative, experimental, before-after-control-impact), response variables (vigilance, group size, resource selection, survival, etc), and general conclusions of each study. In general, we found that most studies focused on short-term effects of energy development on individual ungulate species during initial development phases. Despite the short-term perspective, most studies showed negative effects on some response variable during energy development. However, we argue that short-term, individual species-focused studies are unlikely to demonstrate the cumulative, community-level impacts of broad-scale landscape conversion associated with extensive energy development on wildlife. We illustrate this point with two case studies; cumulative impacts on woodland caribou in Alberta's boreal forest, and mule deer in Wyoming. We conclude by reviewing principles of adaptive management as applied to landscape scale energy development and provide a template for future studies of the effects of energy development on the ecological communities of eastern Montana.

Wildlife Use of Two Existing Bridges and Citizen Documentation of Wildlife Sightings Along State Highway 75, Blaine County, Idaho

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A 26-mi section of State Highway 75 between Timmerman Junction (Jct. with Hwy 20) and the Trail Creek Bridge in Ketchum, Idaho, is likely to be widened because of an increase in traffic volume and traffic safety concerns. The increase in traffic is associated with human population, and job growth. Currently, about 30-50 wildlife-vehicle collisions per year occur on this road section, mostly with mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*). We monitored wildlife passages under two existing bridges across the Big Wood River with photo cameras between 15 April and 11 September 2007. During the same time period, wildlife sightings (dead and alive) were recorded by citizens who traveled the 26-mi road section. Species that passed under the two existing bridges included mule deer (n = 129), red fox (n = 44), mice (n = 35), ground squirrels (n = 21), raccoon (n = 15), weasel (n = 14), red squirrel (n = 10), skunk (n = 5), pine marten (n = 3), black bear (n = 2), and mountain lion (n = 1). Sightings of wildlife (dead and alive) along the entire 26-mi corridor included elk (n = 207), mule deer (n = 117), red fox (n = 24), moose (n = 3), black bear (n = 3), and wolf (n = 2). We conclude that, at least during summer, the two existing bridges were not used by elk, whereas elk did cross the road elsewhere, apparently in large numbers. In addition, there were a minimum of 18 deer- and three elk-vehicle collisions during this time period, indicating that animal-vehicle collisions were substantial, and that mitigation measures may be warranted, both because of human safety and habitat connectivity concerns.

Are Montana's Severe Wildfires Catastrophic or Natural Events?

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Many scientists and forest land managers concur that past fire suppression, grazing, and timber harvesting practices have created unnatural and unhealthy conditions in the dry, ponderosa pine forests of the West. Specifically, such forests are said to carry higher fuel loads and experience fires that are more severe that those that occurred historically. It is unclear, however, how far these generalizations can be extrapolated to other forest systems. Insight into historical forest conditions can be gained through careful consideration of the ecology of plant and animal species that could be considered fire specialists. In western Montana there is one bird species (Black-backed Woodpecker [*Picoides arcticus*]) that is so specialized on exploiting the abundance of beetle larvae in severely burned forests that it is nearly restricted in its habitat distribution to such conditions. This distribution pattern has profound implications because it brings into question the hypothesis that the severe fires we see burning in many, if not most, western forests are "unnatural" or "unhealthy" and suggests instead that severely burned forest conditions across a broad range of forest types must have occurred naturally for millennia. These findings highlight the fact that there are ecological benefits associated with severe fire and suggest that the presence and importance of severe fire may be much broader than what has been assumed on the basis of historical fire-scar studies.

Montana Avian Influenza Surveillance Project

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The USDA and USDI Fish and Wildlife Service initiated a nationwide avian influenza (AI) surveillance project in 2006 in response to concern about the potential expansion of the Highly Pathogenic Avian Influenza (HPAI) H5N1 Asian strain to North America. Montana is a priority state in the nationwide surveillance because it borders Canada and contain both the Pacific and Central Flyways. Montana Fish, Wildlife and Parks (FWP) and USDA/APHIS/ Wildlife Services (WS) have therefore conducted AI surveillance in Montana during the la t two years. Multiple sampling strategies were employed to maximize the chance of detecting HPAI H5N1. Wild and urban live and hunter-harvested bird surveillance targeted specific species spatially distributed across the state and temporally distributed across the sampling period. Environmental sampling was also spatially and temporally distributed. Mortality/ morbidity samples were collected opportunistically during 2006, while mortality transect were added as a mortality/morbidity surveillance technique in 2007. Statewide surveillance was initiated in August 2006 and July 2007 and was conducted for five months each year. FWP and WS collected a total of 2200 and 1502 live and hunter-harvested bird samples during 2006 and 2007, respectively. FWP collected 65 mortality/morbidity sample in 2006 and 48 in 2007, and 120 mortality transects were conducted during 2007. WS collected 998 environmental samples in 2006 and 649 in 2007 statewide. Low pathogenic avian influenza was found in samples from both years as expected. The HPAI H5N1 Asian strain was not detected in Montana or elsewhere in North America during the 2006-2007 surveillance.

Rocks to Riverscapes: Factors Influencing Rocky Mountain Tailed Frog Tadpole Abundance at Multiple Spatial Scales

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The ecology of stream organisms can vary with ontogeny, spatial scale, and network context, especially if the species' range encompasses strong biogeoclimatic gradients. The goal of my study was to evaluate the influence of abiotic and biotic factors on Rocky Mountain tailed frog (*Ascaphus montanus*) tadpole densities across a nested hierarchy of spatial scales in two large, biogeoclimatically distinct stream networks. Specifically, my objectives were to use the Akaike's information criterion (AIC) modeling approach to (1) examine habitat relationships at the microhabitat, reach, and sub-basin scales, (2) examine the importance of periphyton (food) and predation (fish) versus abiotic models for explaining tadpole abundance at the microhabitat and reach scales respectively, (3) evaluate the differences observed in tadpole ecology between the two different stream networks based on the model outputs, and (4) determine whether habitat relationships change for older tadpole age classes. I conducted my surveys in western Montana and northern Idaho. To detect patterns across a hierarchy of spatial scales, I stratified each network into basins, reaches, and channel units, and randomly sampled a minimum of 240 channel units in each, from headwaters to the largest stream order occupied by tadpoles. Tadpoles were relatively abundant and ubiquitous in both stream networks. The lowest ranking, best fitting, AIC model

(abiotic and biotic) for tadpole densities differed between the age classes, across each scale, and between the two stream networks. My findings illustrate the potential problems with the typical habitat modeling and "one size fits all" approach to managing sensitive stream taxa.

Modeling Utilization Distributions in Space and Time

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Van Winkle's (1975) concept of the utilization distribution (UD) has seeded important progress in home-range studies, where it forms the quantity of interest when modeling frequency of animal occurrence in two-dimensional space. However, it lacks generality. We extend the definition of the UD to encompass the four dimensions of space and time. We then extend the application of kernel home range estimation methods to enable estimation of UDs in this higher-dimensional space. In particular, our extension of the product kernel estimator incorporates a new kernel appropriate for circularly distributed covariates, like day of year. Using Monte Carlo simulations, we examine the performance of temporally dynamic UD models. Empirical application of such models is illustrated by estimating the UDs of bighorn sheep (*Ovis canadensis*) in the Many Glacier area of Glacier National Park, Montana. For this application, we model UDs in three dimensions that include geographic (x,y) coordinates and day of year.

Grizzly Bear Density in Glacier National Park

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We present the first rigorous estimate of grizzly bear (*Ursus arctos*) population density and distribution in and around Glacier National Park (GNP), Montana. We used genetic analysis to identify individual bears from hair samples collected via two concurrent sampling methods: systematically distributed, baited, barbed–wire hair traps and unbaited bear rub trees along trails. This study is the first to use detections from rub tree sampling to improve the precision of population estimates made with data from hair traps. We used the Huggins closed mixture model in program MARK to estimate total population size and developed a method to account for heterogeneity caused by unequal access to rub trees. We also developed a new method to correct our estimate for lack of geographic closure based on radio–collared bear locations weighted by mean distance from the study area edge to account for uneven distribution of bears on the sampling grid. Adjusted for closure, the average number of grizzly

bears in our study area was 240.7 ($CI_{95\%}$: 202–303) in 1998 and 240.6 bear ($CI_{95\%}$: 205 304) in 2000. Mean grizzly bear density was 30 bears/1000 km^2 with 2.4 times more bears detected per hair trap inside than outside GNP. We provide ba eline information important for managing one of the few remaining populations of grizzlies in the contiguous United tates

Mining-Related Contaminants in Osprey Along the Upper Clark Fork River

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Osprey (*Pandion haliaetus*) are widely recognized as environmental sentinels of the health of aquatic ecosystems. Until the time of fledging, nestlings feed exclusively on fish caught within a few kilometers of the nest. Therefore, tissues of these young birds reflect the level of contamination of local fish and more generally, the aquatic ecosystems they inhabit. Ospreys are nesting along the Upper Clark Fork River corridor, which is the largest site on the Environmental Protection Agency's National Priorities (Superfund) List for cleanup. Small blood samples can be easily obtained from the chicks, making them ideal subjects for assessing the success of remediation projects that are currently underway. We have started monitoring the levels of priority pollutants (arsenic, cadmium, lead, copper, zinc, mercury and selenium) in Osprey chicks along a 250-km section of the Clark Fork River. Objectives are to establish current contaminant status, pinpoint pollution hotspots, and assess the success of restoration efforts. Our results suggest mercury to be of highest concern with blood levels of up to 500 micrograms per liter (reference dose for human health is 5.8). Interestingly, we found mercury levels increased in downstream direction, in contrast to concentrations of other pollutants. Reasons may be different sources of mercury such as historic placer mines and the presence of contaminated wetlands where mercury can be transformed into more bioavailable methylmercury. Blood levels of selenium are also elevated throughout the Upper Clark Fork River drainage. We discussed the implications for restoration and remediation of the Clark Fork River.

Bat Conservation on the Flathead Indian Reservation

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The Confederated Salish and Kootenai Tribes' Wildlife Management Program is working on conservation projects to benefit bats on the Flathead Indian Reservation. The Reservation has at least eight species of bats including Townsend's big-eared bat (*Corynorhinus townsendii*) a state listed 'Species of Concern.' One of only five known or suspected big-eared bat maternity colonies in the state is located in an abandoned mine on the Reservation. Surveys have confirmed that C. townsendii and other bat species are using other abandoned mines for hibernacula and roost sites. In August 2007, two bat-friendly gates were installed with cost-share funding from the Natural Resource Conservation ervice, Wildlife Habitat

Incentive Program. Within less than one week, big-eared bats were observed roosting in one of the gated mines. In 2008, a third bat-friendly gate will be constructed and mine surveys will be conducted to identify if there is a need for additional gating projects. Long-term monitoring of bat activity at gated sites will provide information on gate success. Additional plans include 1) Reservation-wide baseline field inventories to gain information on species distributions and key resource needs, 2) the construction of roosting structures to provide additional bat habitat, and 3) the distribution of educational materials and presentations to increase public awareness of the benefits of bats.

Efforts to Re-Establish Northern Leopard Frogs on the Flathead Indian Reservation

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The northern leopard frog (*Rana pipiens*) has disappeared from much of its recorded range in western Montana including the Flathead Indian Reservation. In 2001, the Confederated Salish and Kootenai Tribes' Wildlife Management Program began efforts to re-establish northern leopard frog on the Reservation. Preliminary studies included: 1) genetic sampling of remaining northern leopard frog populations in western Montana and potential source populations east of the Continental Divide for relatedness; 2) chytrid fungus testing of source populations and Columbia spotted frogs (*R. luteiventris*) at potential release sites; and 3) testing methodology for rearing tadpoles. Beginning in 2003, we translocated egg masses from source populations to the Reservation. We achieved highest success in hatching eggs and rearing hatchlings indoors in tanks. Rearing of tadpoles in outdoor enclosures imbedded in wetlands had mixed success in terms of mortality and growth. After several years, we concluded the disadvantages of enclosures outweighed the benefits. From 2003 to 2005 we focused our efforts at one release site. Although we located many metamorphs during fall surveys, we were unable to document over-wintering success. In 2006 and 2007, we chose a second release site. In 2007, we found northern leopard frog at the second site that were large enough to suggest some individuals had over-wintered successfully. We also observed extensive movements of frogs following metamorphosis. We plan to continue reintroduction efforts with the goal of establishing five successful breeding populations on the Reservation.

A Novel, Automated Remote Sensing Tool for Detecting Wolves

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The USDA Fish and Wildlife Service recently propo ed removing ndangered Specie Act protections for wolves in the Northern Rockies. As the wolf (*Canis lupus*) ı delisted, federal funding to monitor and protect the wolf population will disappear. The task of monitoring wolves must be taken up by the states with limited resources therefore new monitoring methods that are robust yet cost-effective are nece sary. We have developed an automated remote sensing tool, "howlbox," that can broadca t a wolf howl, record responses, then hibernate for a specified time period until the next scheduled howl broadcast. The howlbox is non-invasive and is ideal for use in Wilderness Areas where access is difficult and sampling is labor intensive and expensive. We recently tested the howlbox on wild wolves in the Bitterroot Valley and obtained 12 responses over 2.5 days of remote sampling. We plan to test the howlbox widely on radio-collared packs in the summer of 2008 to further refine this novel tool. The howlbox can also be used in roaded areas to decrease the costs and concerns associated with trapping and radio-collaring wolves for monitoring purposes.

Candidate Gene Microsatellite Variation is Associated with Parasitism in Wild Bighorn Sheep

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The loss of genetic variation in host populations is thought to increase host susceptibility to parasites. However, few data exist to test this hypothesis in natural populations. Bighorn sheep (*Ovis canadensis canadensis*) populations occasionally suffer disease-induced population declines, allowing us to test for associations between reduced genetic variation and parasitism in this species. Here we show that individual mean heterozygosity for 15 microsatellite loci is associated with lungworm abundance (*Protostrongylus* spp.) in a small, recently bottlenecked population of bighorn sheep (linear regression , $R^2 = 0.339$, $P = 0.007$). This association remains significant for seven microsatellites located in genes ($P = 0.010$), but not for eight neutral microsatellites ($P = 0.306$). Furthermore, heterozygotes at three of four microsatellites located within disease-related genes had lower lungworm burdens. This study corroborates theoretical findings that increased parasitism and disease may be a consequence of reduced heterozygosity in wild populations, and that certain individual loci influence

parasite resistance. The results illustrate the usefulness of using genomic information, strong candidate genes, and noninvasive sampling for monitoring both genetic variation and fitness-related traits, such as parasite resistance, in natural populations.

Home Range and Habitat Selection of the North American Porcupine in the Bitterroot Valley

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In the past several decades it has been noted by Montana Fish, Wildlife, and Parks biologists that the occurrence of porcupine (*Erethizon dorsatum*) sightings in western Montana has been reduced. This observation sparked interest in current population demographics within this area. During the summer of 2006 surveys requesting information on sightings of porcupines or their sign was distributed throughout western Montana. The results from this survey allowed for further narrowing of the study area to the Bitterroot valley. In the spring of 2007 trapping and radio-collaring of individuals began in the Bitterroots in hopes of targeting home range and habitat selection at the third and fourth order, with notes made on mortality and reproduction. The spring trapping session resulted in the successful capture of seven individuals on both private and public lands. Individual home ranges will be calculated using a minimum convex polygon due to small sample size. Habitat selection will be quantified by building resource selection functions using both land cover data from satellite imagery as well as data collected on the ground. Trapping and data collection will continue into the summer of 2008.

Wildlife Information in Montana: Acquisition, Management, and Dissemination by the Montana Natural Heritage Program and Montana Department of Fish, Wildlife and Parks

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The Montana Natural Heritage Program (MNHP) was established by the Montana State Legislature in 1983 and charged with statutory responsibility for the acquisition, storage, and retrieval of information documenting Montana's flora, fauna, and biological communities. To provide the information needed for wildlife stewardship, Montana Fish, Wildlife, and Parks (MFWP) has long collected and managed data on harvested animal species, primarily at local or regional offices. Since the 1990s, information on harvested as well as federally listed animals and nongame fishes has increasingly been managed by the agency's Information Management Bureau. MNHP and MFWP started working more closely on gathering, managing, and distributing information on Montana's vertebrate animal species during the development of Montana's Comprehensive Fish and Wildlife Conservation

Strategy (CFWCS). After development of the CFWCS, MNHP and MFWP have continued to integrate management of information on Montana's animal species. This recently culminated in the development of an MOU which outlines the relationship and respective roles of the two agencies in the acquisition, management, and dissemination of animal information. MFWP and MNHP closely coordinate management of animal information in shared statewide databases with MFWP solely responsible for harvested species data and data associated with scientific collector's permits. MFWP takes the lead on data associated with managed nongame species while MNHP takes the lead on unmanaged nongame species. Both agencies have recently developed a variety of map products for Montana's wildlife, and these are delivered with different levels of access to the general public and agency biologists or resource managers.

Patterns and Consequences of Columbia Spotted Frog Size at Metamorphosis in High Elevation Ecosystems

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The importance of temporary ponds and wetlands on the landscape is a central point of debate in wetland conservation. Amphibian ecologists argue that small wetlands are often essential to the maintenance of amphibian populations. However, few studies have examined the importance of small, temporary ponds to amphibian populations in montane ecosystems. We conducted a mark-recapture study of a Columbia spotted frog (*Rana luteiventris*) population in the Bitterroot Mountains from 2001-2007, catching metamorph, juvenile, and adult frogs each year. Using pond-specific batch marks each year, we tracked production and survival of metamorphs emerging from ephemeral ponds and permanent ponds over time. Specifically, we wanted to know (1) if metamorphs emerging from ephemeral ponds and wetlands were smaller in size than those emerging from permanent water bodies, (2) whether metamorphs showed higher or lower rates of dispersal depending on their pond type of origin, and (3) whether size at metamorphosis correlated positively with apparent survival probabilities. Preliminary results indicate that metamorphs from ephemeral ponds are smaller in mass than metamorphs from permanent ponds, but that these differences are no longer as apparent at one year. Metamorphs from ephemeral ponds show higher rates of dispersal than those from permanent ponds. To date there is no correlation between size at metamorphosis and apparent survival to one year. Further analyses will determine whether long-term differences in survival are detected. These results will clarify the contribution of ephemeral wetlands to montane amphibian populations.

Influence of Beaver on Brook Trout Invasion and Native Westslope Cutthroat Trout Displacement in Rocky Mountain Streams of Southwestern Montana

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Invasion of ecosystems by nonnative species is often responsible for reshaping natural biological communities. In the Rocky Mountains, brook trout (*Salvelinus fontinalis*) invasion has been implicated in the decline of westslope cutthroat trout (*Oncorhynchus clarkii lewisi*), a native species of special concern in Montana. Although research has established that negative interactions between these species likely occur at the juvenile stage, there remain gaps in our understanding of the landscape factors that influence the extent of invasion, and resulting cutthroat declines. For example, beaver (*Castor canadensis*) are capable of altering stream habitat characteristics considerably, but we do not know how beaver disturbance influences brook trout invasion success, and the consequences for native cutthroat trout. To address this, I used temperature loggers, mark-recapture, and habitat surveys to establish how beaver affect (1) brook and cutthroat trout distributions within watersheds, and (2) species interactions between cutthroat and brook trout. Distribution and temperature data show that beaver-induced stream warming sustains brook trout invasion at higher elevations, while brook trout presence acts to reduce cutthroat trout growth rates. Ongoing analyses of growth rates from scales, and examination of demographic rates of both species will lend greater insight into how beaver impact this system.

The Effect of Climate Change on Wolverines

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Wolverines (*Gulo gulo*) are climate specialists. They obligately den in snow and their movements year-around are almost exclusively confined to areas characterized by snow that persists into mid May. This pattern occurred historically, occurs currently worldwide, and likely will occur in the future. We investigated the potential impacts of climate change on wolverine habitat by analyzing observed and projected spring snow cover. We determined the temperature threshold for different probabilities of snow cover associated with wolverine denning and range through analysis of snow cover from MODIS satellite data (See Copeland et al. talk this session) and 800 m resolution PRISM temperature data. We then used temperature projections from nine general circulation models, downscaled to 8 km spatial resolution to project. By 2050, snow cover suitable for wolverine dens could decline by up to 95 percent in the lower 48 states of the U.S. Refugia may persist in high mountain areas of Colorado and California, but wolverines have been extirpated from these areas.

The Impacts of Climate Change on Snow Dependent Mammals

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In the western United States, much of the strongest data demonstrating climate change during the late 20th century are related to changes in snowpack. Snowpack is a particularly sensitive to climate change; shifts from snow to rain occur in many areas with relatively modest temperature increases. Many mammals are specifically snow adapted as evidenced by changes in pelage color and a variety of snow adapted morphologies. The snowshoe hare, for example, has large feet which aid in flotation and turns white in the winter. Both morphology and pelage change are maladaptive in a snow-free environment. Timing of pelage change is particularly critical. Lynx are also morphologically highly adapted to snow, having large feet, long legs, and a light, fragile bone structure. While not as morphologically linked to snow as lynx or snowshoe hares, wolverines obligately den in deep snow. All known reproductive dens, worldwide, occur within areas persistently snow covered through May 15. Further, areas that are snow covered in May contained most (91%) of the year-around telemetry locations in 6 studies in the western U.S. We transformed areas of snowpack associated with wolverine denning and range into climatic parameters by correlating the developed MODIS snow surface with high resolution climate surfaces developed by NOAA We then used "sharpened" GCM projections developed at Oregon State University. By 2050, in three representative GCMs, virtually all persistent spring snow is gone. Unless wolverine show great plasticity, they will be gone as well. Because snow adapted organisms are adapted to very specific attributes of snow such as the period of snow coverage, snow morphology, or spring snow melt, their responses to small changes in climate can be expected to be both large and rapid.

Interactions Among Gray Wolves and Coyote in Yellowstone National Park

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Few studies to date examine the effects of introduced top-carnivores on other carnivores. Interspecific interactions between competing predators can influence ecosystem function, trophic structure, and the distribution and density of sympatric predator species. The recovery of gray wolves (*Canis lupus*) in Yellowstone ational Park provides a unique opportunity to study intraguild interactions with coyotes (*Canis latrans*), which have persisted without wolves for > 60 yrs. Our objectives were to quantify observed wolf-coyote interactions and describe the context and degree of competition and coexistence. Using radio-collared wolves to observe behavioral interactions with other species, we documented 337 wolf-coyote interactions over twelve years. Most (75%) interactions occurred at ungulate carcass sites. Wolves initiated (85%), outnumbered (39%) and dominated (91%) most interactions. Wolves mostly (79%) chased coyotes without physical contact; however 25 interactions resulted in a

coyote death. Interactions decreased over time suggesting coyote adaptation and/or a decline in coyote density. In most (80%) fatal interactions, wolves outnumbered coyotes. However, wolves did not outnumber coyotes in interactions (n = 18) where coyotes chased or attacked/harassed wolves. Our data suggests that there are circumstances where coyote group size influences the outcome of interactions. Although coyote density may have decreased since the reintroduction of wolves, and wolves represent a mortality risk to coyotes, the benefits of utilizing wolf-killed carcasses outweigh the potential costs of interactions with wolves.

Wildlife Provisions in the Climate Security Act of 2007

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The Climate Security Act (CSA or Warner-Lieberman) currently under consideration in Congress includes provisions for funding state and federal wildlife conservation activities on a scale unprecedented since passage of the Pittman Robertson Act of 1937. The bill establishes a cap and trade provision on carbon emissions in order to curb accumulation of greenhouse gases. The CSA devotes 18 percent of the proceeds from auction of emissions permits to adaptation measures that help U.S. wildlife and natural resources survive global warming. As currently written, about $175 billion would be allocated in this way through the initial period (to 2030) or $9.3 billion/year. The bulk of this would go to state wildlife agencies (35%), DOI wildlife programs (19%), the Land and Water Conservation Fund for habitat acquisitions (10%), COE for aquatic and estuarine ecosystems (10%), NOAA (10%), USFS (5%), EPA (5%), DOI cooperative grant program (5%), and Tribal fish and wildlife agencies (1%). Professional societies like the Montana Chapter must play an active role in helping Sen. Baucus assure that these provisions for wildlife remain in the CSA.

Mountain States Transmission Intertie 500kV, Wildlife Impacts in the Face of Energy Development

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Increasing electric consumption, population growth, increasing awareness of global warming, legislation, and insufficient infrastructure are combining to drive demand for new sources of electricity. Wind, clean coal, natural gas and possibly nuclear generation are likely new sources of electric generation. Most locations for new generation are long distances from the demand/population centers, requiring construction of new transmission facilities to deliver electricity. Construction of new generation and transmission facilities has the potential to impact wildlife on many levels. With a paradigm shift in the energy business toward cleaner energy production, innovative approaches for assessing impacts to wildlife are important to minimize wildlife impacts. Northwestern Energy, formerly know as Montana Power, is an investor-owned utility, proposing to build a 500-kV transmission line from southeastern Idaho to southwestern Montana. The proposed line would: extend 350-390 mi, be constructed of lattice steel towers and tubular steel self-supporting towers with an average height of 110-130 ft, require a right-of-way width approximately 220 ft, and have an average span of approximately 1500 ft between towers. Potential wildlife impacts are being identified through

a combination on Geographic Information System analyses, field verification, per onal communication with local agencies, and existing literature. Further a e sment(s) of impact to specific species and habitats is anticipated during and after construction through field investigations. Continued input of wildlife professionals is encouraged and appreciated.

Estimating Resource Utilization Functions: Correcting for Behavior Associated with Central-Place Foraging

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Most resource-selection models assume that space use is uniform. However, in the case of central-place foragers, the null utilization distribution (UD) is not uniform but rather a circular-normal distribution centered about the central place. Estimating resource selection without correcting for the behavior associated with central-place foraging will result in models biased towards habitats closest to the central place. We present a method for estimating a resource-utilization function (RUF) that explicitly accounts for central-place-foraging behavior and provides a more accurate picture of resource use when using UDs to measure resource use. The bias-corrected RUF uses a fixed-kernel-density estimator to calculate a UD, and then uses the difference between the surface of this UD and the surface of a circular-normal UD to calculate corrected space-use probabilities. The individual UD cell probabilities are then used as a response variable in a modeling framework to identify explanatory variables that best explain space use. We demonstrate the use of bias-corrected RUFs using telemetry data from northern goshawks (*Accipiter gentilis*) breeding in Idaho. Advantages of the bias-corrected RUF include a less-biased picture of habitat selection by central-place foragers and the ability to map habitat selection using the resulting model without first needing to know nest-site locations.

Quantifying Ecological Process Using Landscape Genetics: A Study of Boreal Toad Connectivity in Yellowstone National Park

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The boreal toad (*Bufo boreas boreas*) is a locally abundant, patchily distributed species thought to be in decline throughout most of its range. Recapture rates tend to be low, making demographically based estimates of non-breeding habitat use and population connectivity unreliable. Therefore we used a landscape genetics approach, which quantifies the impact of landscape composition, configuration and matrix quality on population connectivity using genetic markers. We surveyed boreal toad breeding sites throughout Yellowstone National Park and collected microsatellite genotype data (15 loci, $n = 953$). We used an algorithmic approach (Random Forests) to build multi-scale models of boreal toad connectivity. We found 1) boreal toad connectivity is a function of three ecological processes (habitat permeability, topographic morphology, and temperature-moisture regimes), 2) these ecological processes

operate at multiple scales, and 3) boreal toad connectivity is hierarchical with metrics operating at coarser spatial and temporal scales driving connectivity between genetic clusters; while metrics operating at finer spatial and temporal scales drive connectivity within a genetic cluster. In addition, we found heterozygosity based metrics of genetic connectivity (F_{ST}) explained more variation in coarse processes versus fine scale processes. Conversely, allele frequency based metrics (D_{ps}) of genetic connectivity explained the most variation in fine-scale processes detected recent landscape change (fire, drought, impervious surfaces). In the future, the approach we developed can be used to predict the impact of landscape change on Boreal Toad connectivity. Additionally, the analytical methods developed can be applied in any species or system with appropriate landscape and genetic data.

Wildlife-Friendly Practices on Montana's Private Lands

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The majority of Montana is privately held, maintained for agricultural production, and provides much of Montana's wildlife habitat. Landowners utilize different wildlife habitat management strategies according to location, type of agriculture production, and adjacent land value and use. In December 2007 Montana farmers and ranchers received a questionnaire included in the Montana Farm Bureau Federation newsletter to address trade-offs landowners consider when choosing wildlife-related land management practices. Within the first month, 77 questionnaires were returned (8% response rate). Preliminary results indicate about half (49%) of respondents do not participate in a natural resource conservation program, 17% participate in NRCS Environmental Quality Incentive Program (EQUIP), and 14 percent participate in Montana FWP's Block Management Program. Of those who participate in an economic incentive program or enterprise, 60 percent derive < 5 percent of annual ranch income from participation in these programs. Nearly half (43%) of respondents who participate in an economically motivated conservation program feel that the income they receive offsets wildlife damage to their land/crops. Regardless of economic benefit, most farmers and ranchers (63%) practice wildlife tolerance on their lands and 58 percent provide water for wildlife throughout the year. Some improve wildlife habitat by planting food plots (18%), fencing riparian corridors (14%) and delay mowing for nesting birds (8%). These preliminary results indicate that landowners who receive some compensation for providing wildlife habitat may be more likely to tolerate wildlife abundance, and place emphasis on creating and maintaining wildlife habitat on their lands.

Relationships Among Ungulate Browse, Willow Community Structure, and Migratory Landbirds at Red Rock Lakes National Wildlife Refuge

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Critical relationships exist between vegetation structure and avian diversity and abundance. Browsing by herbivores can lead to changes in the structural heterogeneity and species composition of plant communities, resulting in decreased use of heavily browsed habitats by avian species. We assessed the current levels of browse by native ungulates and resulting effects on composition and structure of willow communities on Red Rock Lakes National Wildlife Refuge in southwestern Montana. We also determined abundance and community composition of breeding land birds in these habitats and related these to willow structure. Bird counts and vegetation sampling were conducted along two riparian corridors and one fen habitat during the summers of 2006-2007. Our results indicate current levels of ungulate browsing on the Refuge are low to moderate. Species composition of willow communities varied between riparian and fen habitats and contributed to differences in willow volume and structural heterogeneity. Five species of birds (Yellow Warbler, Common Yellowthroat, Lincoln's Sparrow, White-crowned Sparrow and Song Sparrow) were used for examining relationships between avian abundance and willow vegetation characteristics. Additional vegetation sampling in conjunction with improved monitoring of ungulate populations utilizing the Refuge will allow managers to make informed decisions concerning ungulate harvest limits and conservation of willow communities.

Auditing a Monitoring Program: Can Citizen Science Represent Wildlife Activity along Highways?

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Mitigating wildlife barriers caused by transportation corridors requires data on wildlife activity to effectively locate sites for mitigation measures. *Road Watch in the Pass* (RW) is a pioneering citizen science monitoring program that engages citizens in documenting wildlife activity along a highway in Crowsnest Pass, Alberta, Canada. There are plans to upgrade Highway 3 to four lanes, with resulting increased traffic volume and speed. The information RW collects is intended to assist mitigation efforts. This study evaluates the ability of RW to represent visible wildlife activity along Highway 3. A systematic driving survey was

created to accurately document visible wildlife within 100 m of the highway. This was used to compare its spatial, temporal, and species composition wildlife observation distributions to the information gathered by RW using various analyses. Due to its unsystematic nature and lack of sampling effort documentation, RW is limited in its ability to make some statistical conclusions, limiting some analyses and conclusions of this study. Despite these problems, the spatial distribution of RW wildlife observations corresponded with the systematic dataset. Differences in observation rates by time of day and season were displayed by the systematic dataset, while RW cannot provide unbiased temporal information. Both datasets documented high levels of deer observations and low levels of non-deer observations, indicating they are effective at documenting deer but not effective at observing non-deer species. Several modifications are recommended to enhance the scientific rigor of RW and provide guidance for groups aiming to use a similar volunteer highway wildlife monitoring program.

Identifying Linkage Zones for Grizzly Bears Across a Section of Highway 3 in Southeast British Columbia

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As part of recovery efforts for a small, fragmented, and threatened brown bear (*Ursus arctos*) population in North America shared by Canada and the USA, we used DNA and radio telemetry based methods to identify linkage zones in a fragmented habitat. A human settlement and transportation corridor fragments the international south Purcell-Yaak population (population ~ 50 animals) and consequently threatens its long-term persistence. Because bears are relatively sparse in this population, and sample sizes consequently low, we used two complementary methods -- ecological modeling from hair-snag DNA surveys and Geographic Positioning System (GPS) radio telemetry—to identify "linkage zones" to facilitate improving natural inter-population exchange of animals with adjacent populations, a requirement for recovery. We genetically sampled wild brown bears at 170 hair-snag sites on both sides of the human corridor in 2004 and 2005. Hair follicles were used as a source of DNA to develop microsatellite genotypes that identified 65 different bears at 54 sites totaling 124 capture events. We then characterized the landscape for 24 ecological and human variables (terrain ruggedness, riparian, forest cover, roads, settlement, etc). We correlated these variables to bear presence and absence in a multiple logistic regression and used Geographic Information Systems (GIS) to develop a spatially-explicit "resource selection function" model to predict bear occurrence across our 9500-km^2 study area. We used the model to predict areas of high use (core habitat) and linkage habitat that connects core areas. We also put GPS radio collars on eight brown bears that were captured adjacent to the human corridor. The radio collars acquired hourly locations throughout the non-denning seasons. These data revealed the presence of areas where bears crossed the human corridor and corroborated our predictive model. It is challenging to obtain reliable and objective results in a system with few bears, but we reached our goal of identifying linkage and core habitat

because we used both DNA-based ecological modeling and GPS radio telemetry method . Neither method on its own was sufficient, but each contributed significant information to the ecological solution and provided independent validation of our conclusions. These methods may be of use for other sparse bear populations around the world where conservation solutions are required but low bear numbers make research challenging.

Anesthesia of Grizzly and Black Bears Using Xylazine, Zolazepam, and Tiletamine and Its Reversal Using Yohimbine

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Wildlife managers and research biologists are continuously looking to improve their field methods and reduce mortality to study animals during capture. This is especially true when handling individual bears from isolated, declining populations. Bear researchers require an anesthetic that is not dangerous to humans, provides a wide safety margin for bears, requires a low volume dose for efficient delivery, maintains physiological homeostasis, and is reversible. No one chemical can meet all these requirements. I tested the use of Xylazine, Zolazepam and Tiletamine (XZT) in combination on grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) to determine the quality of anesthesia it produces and its potential to be reversed Bears were captured as part of on going research in western Montana, northern Idaho, and southeast British Columbia. Bears were captured in foot snares, and delivery systems varied according to capture episode. All bears were administered supplemental oxygen at 3 liter/hour. Bears anesthetized with XZT and reversed with yohimbine recovered from anesthesia faster than bears anesthetized with Tiletamine/Zolazepam combinations. They required smaller dose volume, showed similar induction rates, and were able to maintain physical parameters close to homeostasis. The XZT combination tested is a viable option for safe, effective handling of bears. The synergistic effect of these three drugs allows some of the anesthesia to be reversed allowing bears to recover faster. This permits bears to return to normal body function sooner, reduces vulnerability to predation and allows animals to resume normal behavior quicker.

Management Considerations for Designing Carnivore Highway Crossings

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There has been significant confusion conflict over appropriate highway crossings for carnivores and other species. The concepts of habitat connectivity and wildlife crossing have becoming more established, within resource agencies, highway departments, wildlife professionals and the general public. Various problems still emerge, often because wildlife biologists are not well trained in appropriate highway crossing designs for carnivores and other wildlife species and do not have experience in wildlife crossing design and implementation. State Department's of Transportation (DOT) also have concerns about wildlife crossing costs and efficacy. The result can be disagreements between biologists and engineers or transportation agencies and resource agencies. Gridlock and poor relation hips between agencies are often unexpected outcomes. The paper and presentation deals with 1) How biologist's can develop good working relationships with engineers and highway

departments, 2) How to successfully plan for wildlife crossings and wildlife habitat linkages with DOT's, 3) Selecting appropriate wildlife crossings for carnivores and other species, and 4) Wildlife crossing follow-up and learning from successes.

Wolverine Gene Flow Across a Narrow and Disappearing Climatic Envelope

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Wolverines (*Gulo gulo*) are climate specialists that have components of their life history that require snow. Our research team initially investigated the potential impacts of climate change on wolverine habitat by analyzing observed and projected spring snow cover using MODIS satellite data. The spring snow cover is strongly correlated with year-round wolverine locations and wolverine dens (See Copeland et al. talk this session). In this work we investigate the degree to which spring snow influences movement and gene flow of wolverines by using genetic-based landscape resistance modeling. Using Mantel tests, we found that both Euclidean distance and landscape resistance distances were significantly correlated with genetic distances among all pairs of wolverine. However, partial Mantel tests reveal that Euclidean distance is not significant when removing the effect of landscape distance. Alternatively landscape distance is significant when removing the effect of Euclidean distance. This result supports our suggestion that the spring snow bioclimatic niche is important to the movement of wolverine; a niche that is predicted to rapidly disappear (See McKelvey et al. talk this session).

Local and Landscape-Scale Influences on the Occurrence and Density of the Idaho Giant Salamander

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Species distribution and abundance depend on a balance between large-scale, landscape processes and small-scale, local processes. To successfully manage populations in regions with anthropogenic disturbances and habitat fragmentation, an understanding of important processes at each spatial scale is important. We use a model selection approach to identify the appropriate spatial scale to manage a stream salamander species Idaho giant salamander (*Dicamptodon atterimus*) in the Lochsa River subbasin, Idaho. We use data from field surveys to compare evidence of support for landscape and local-scale models that explain salamander patch occurrence and relative density data. Landscape-scale models include covariates that reflect assumptions of metapopulation theory, while local-scale models include covariates that reflect patch quality. Our results suggest that landscape-scale processes are important controls on salamander occupancy. Specifically, we found that probability of salamander

occurrence was greatest in roadless drainages and lowest in isolated stream network. In addition, we found that the relative density of Idaho giant salamander was greatest in stream with a high proportion of embedded substrate and fine sediment. These results suggest that giant salamander patches are spatially structured within stream networks and that *D. attenuatus* has broad habitat requirements within a patch. We suggest that management efforts focus on protecting roadless areas and restoring stream connectivity in human-impacted areas, rather than on improving habitat quality within a stream.

Gray Wolves and Livestock in Montana: Recent History of Damage Management

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The Montana gray wolf (*Canis lupus*)population grew from two wolves in 1979 to a minimum of 316 by late 2006. Resolving conflicts, both perceived and real, between wolves and livestock was a dominant social issue for the federal recovery program, and it remains so today. The USDI Fish and Wildlife Service and now Montana Fish, Wildlife and Parks work with USDA-APHIS-Wildlife Services to reduce depredation risks and address wolf-related conflicts through a combination of non-lethal and lethal management tools. The number of wolf complaints investigated from 1987-2006 increased as the population increased and expanded its distribution into Montana after reintroduction into Yellowstone National Park and central Idaho in 1995/96. Montana wolf packs routinely encountered livestock, though wolf depredation was a relatively rare cause of livestock death and difficult to predict or prevent. Cattle and sheep were killed most often from March to October although losses were confirmed each month. From 1987-2006, wolves killed 230 cattle, and 436 sheep. However, confirmed losses probably represent a fraction of actual wolf losses. Few other types of livestock classes were killed. Conflicts are addressed on a case-by-case basis, striving to connect the agency response to the damage in space and time and to decrease the potential for future losses. Lethal control is implemented incrementally after predation was verified, and 254 wolves were killed from 1987–2006. Only complete removal of either wolves or livestock eliminates the potential for wolf depredation. The continued presence of a viable wolf population requires that a wide variety of non-lethal and lethal tools be investigated and implemented. That combination will also be required to maintain local public tolerance of wolves where the two overlap and to foster broad public acceptance of techniques used to minimize conflicts. Resolving wolf-livestock conflicts at a local scale is but one component of a larger state wolf conservation and management program. Upon delisting, regulated public harvest will allow us to more proactively manage the population.

Lower Red Rock Lake and Adjacent Wetlands: Preliminary Understanding of Their Geohydrology

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We have been studying the wetland systems at Red Rock Lakes National Wildlife Refuge in the Centennial Valley of Southwest Montana for several years. Our charge was to provide recommendations about water levels for optimum long term management of waterbirds. To do so, we recognized that we first needed to gain an understanding of the interacting role of water sources and soils in determining submergent and emergent plant communities. The Centennial Valley is tectonically active. That ultimately drives the location of wetlands and is responsible for the generally sloping elevation of wetland bottoms from North (highest) to South. Additionally, the area's geomorphology is dominated by glacial and related alluvial processes that drive soil development and shallow groundwater movement. Using standard hydrologic techniques, particularly shallow wells and piezometers, we have begun to gain an understanding of the prevalence of groundwater discharge in Lower Red Rock Lake and the adjacent semipermanent emergent sedge wetlands. We describe some of the initial patterns that have been uncovered using clustering and classification and regression tree statistical methods. Our next efforts will focus on multivariate analyses and modeling of soil parameters, near surface stratigraphy, hydrologic factors, and aquatic plant communities.

Status of Tribal Wildlife Mitigation Projects on the Flathead Indian Reservation

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In 2000 the Confederated Salish and Kootenai Tribes, Pennsylvania Power and Light Montana, and the Department of Interior reached a settlement agreement that was adopted by the Federal Energy Regulatory Commission to mitigate the negative impacts of the operation of Kerr dam on fish and wildlife resources on the Flathead Indian Reservation. The settlement included funds for habitat acquisition and restoration, monitoring and wildlife enhancement projects. Habitat acquisitions were to be completed within 5 yrs of completing a habitat acquisition and restoration plan. To achieve the mitigation targets, the Tribes chose to both acquire new lands and redirect the management of existing Tribal lands. Acquisitions were completed in 2007. Under Kerr mitigation the Tribes purchased and redirected management of nearly 8000 ac of land for wildlife habitat restoration and management. Additional lands were purchased to offset agricultural uses on Tribal lands that were redirected and to provide more land for the benefit of fish and wildlife resources. This presentation will summarize the

accomplishments that have been achieved and provide a statu report on various ongoing projects within the Tribal Mitigation Program.

Hierarchical Den Selection of Canada Lynx in Western Montana

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We studied den selection of Canada lynx (*Lynx canadensis*) at multiple ecological scales based on 57 dens from 19 females located in western Montana between 1999-2006. We considered three spatial scales in this analysis including the den site (11-m radius circle surrounding dens), den area (100-m radius circle), and den environ (1-km radius surrounding dens). Lynx exhibited habitat selection at all 3 spatial scales. Based on logistic regression, den sites differed from the surrounding den areas in having higher horizontal cover and lo volume. Abundant woody debris from piled logs was the dominant habitat feature at den sites. Female lynx selected den areas with greater spruce-fir tree basal area, higher horizontal cover, and larger-diameter trees compared to random locations within their home ran e Eighty percent of dens were in mature forest stands and 13 percent in mid-seral regeneratin stands; young regenerating (5%) and thinned (either naturally sparse or mechanically thinned) stands with discontinuous canopies (2%) were seldom used. Lynx selected den environs in topographically concave or drainage-like areas, and further from forest edges than random expectation. Maintaining mature and mid-seral regenerating spruce-fir forests with high horizontal cover and abundant woody debris would provide lynx denning habitat in concave, drainage-like basins. Management actions that alter spruce-fir forests to a condition that is sparsely stocked, e.g., mechanically thinned, and with low horizontal cover would create forest conditions that are poorly suited for lynx denning.

The Relationship of Wildlife Management and Land Trasactions on Plum Creek Lands

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Plum Creek is a large private land owner in several western counties where rapid growth is occurring. Population growth in western counties is expected to increase > 70 percent by the year 2030. This presentation will describe how Plum Creek reacts to some of that growth and associated demand for rural recreational properties. Topics of discussion will include existing land use practices that consider fish and wildlife habitats, proactive planning strategies, conservation strategies, and land sales. In 2007 Plum Creek sold ~ 30,000 ac of land in Montana. Conservation sales accounted for most of those sales, including lands associated with the Swan Valley and Blackfoot River watershed. Forest land management practices incorporate the Sustainable Forestry Initiative Standards and voluntary federal agreements such as the Native Fish Habitat Conservation Plan and the Swan Valley Grizzly Bear Conservation Agreement. By design, some conservation measures of these agreements and other land use restrictions are passed to subsequent landowners. Plum Creek's

involvement in regional planning efforts near Seeley Lake and the Thompson Chain of Lakes address issues of wildlife sustainability. New subdivisions by Plum Creek address practices to minimize impacts to wildlife resources at both the broad and site-specific scale.

Differential Habitat Use of Bats Along a Prairie Riparian Corridor in Eastern Montana

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Little attention is devoted to the ecology of bats inhabiting prairie landscapes. Although previous studies indicate the importance of riparian corridors as foraging habitat for prairie bats, resource partitioning within prairie riparian zones is relatively unknown. This study examined bat activity patterns among seven habitat types along the Missouri River in eastern Montana from June-August 2003 and 2004. Acoustic monitoring and mist net captures detected 12 species in the study area, including a considerable expansion of the known range for the spotted bat (*Euderma maculatum*). Acoustic monitoring revealed that bats utilize available habitats at different intensities along the Missouri River in eastern Montana. Riparian forest edge habitat accounted for the highest activity for the entire bat community and the two most common phonic groups detected, 40 kHz and EPFU/LANO/LACI. The 40 kHz phonic group spent relatively equal amounts of time in all other habitat types while the EPFU/LANO/LACI phonic group exhibited a strong bias towards all riparian forest habitats. Riparian forest edge habitat also accounted for the highest foraging attempts per hour for the bat community. This research suggests that riparian cottonwood forest, especially the ecotone between riparian forest and open vegetation, provides important habitat for bats in eastern Montana and might be a limiting factor to bat distributions and abundance on prairie landscapes. Conservation measures to maintain and regenerate cottonwood riparian forests are needed to continue providing important habitat for prairie bats along the Missouri River.

Status of the Western Fence Lizard in Montana

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In Aug, 2002 a biology student at Salish Kootenai College found a dead adult specimen of the Western Fence Lizard (*Sceloporus occidentalis*) along the shore of the Lower Flathead River near Perma on the Flathead Indian Reservation. The discovery represented the first time this species had been reported in Montana. The closest known locality is 240 km to the west in eastern Washington. A survey of the area shortly after its discovery revealed the presence of two adults and two young-of-the-year scattered among eroded sandstone banks along the river. The area occupied by the lizards was ~ 25 m long by 15 m wide. From 2003 to 2006, I undertook repeated surveys of the known locality and surrounding environs. Usually I saw five or fewer individuals with most sightings in the discovery area. Each year, however, a few individuals were sighted outside of the area, including one young-of-the-year in 2006 that was ~ 100 m to the west. In 2007 a September survey resulted in the sighting of seven young-of-the-year and eight juveniles/adults with about half of them in a new area to the north of the existing range. This represented the apparent first major expansion of the population since it was discovered in 2002. Management alternatives for this species are discussed.

Private Lands: Owner Sentiment Regarding Elk Population Season Options, and Hunter Access

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Montana's private landscape has undergone considerable ownership changes in recent years. During this same time, elk (*Cervus elaphus*) populations in the state have continued to increase despite relatively steady hunting pressure and harvest rates. We assessed private landowner opinions of current elk populations, untried season options, and elk hunter access. For the purpose of this study, large contiguous tracts of land (> 640 ac) were considered to provide the greatest opportunity for elk harvest, assuming that hunters have access to it. Therefore, 3310 landowners owning ≥ 640 ac were surveyed in 43 hunting districts. These hunting districts were selected because elk populations in these districts exceeded management objectives. Questionnaires were successfully delivered to a total of 3237 landowners, with 1737 responses resulting in a 54-percent response rate. Survey results indicated that while a considerable majority (80%) of the landowners with elk typically on their property during general elk season allowed some form of elk hunter access in 2006, their opinions regarding elk populations and hunter access varied widely. Additionally, resident and nonresident landowners not only statistically differed ($P < 0.05$) in almost all of their opinions, but also varied considerably within their groups depending on the topic. Agency big game managers and decision makers should recognize that private landowner sentiments toward elk populations, management, and hunter access are not always as straightforward as many believe.

Effects of Cattle Grazing on Small Mammal Communities at Red Rock Lakes National Wildlife Refuge

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Cattle grazing is a common land use on public land in the Intermountain West that often has varied and complex effects on wildlife. However, many studies of wildlife response to grazing only compare grazed versus ungrazed treatments, ignoring the dynamic nature of grazing and the many levels of grazing intensity and frequency commonly utilized. We undertook the current study to better understand the response of small mammals to the frequency of cattle grazing in wet meadow habitats on Red Rock Lakes NWR. Three adjacent grazing units were selected for study that provided a wide range of grazing frequencies (1, 3, and 8 yrs of rest). Two randomly placed trapping grids were placed within the *Juncus balticus – Carex praegracilis* vegetative alliance (wet meadow) in each unit. Trapping occurred throughout July, with each unit sampled 3 days during each of 3 primary trapping sessions. We captured and marked 357 individuals, and had 174 recaptures. Voles (*Microtus* spp.) comprised nearly 99 percent of individuals captured, with 2 deer mice (*Peromyscus maniculatus*), and one common shrew (*Sorex cinereus*) captured. Our results indicated that

vole abundance increased with increasing rest from grazing. Unlike abundance, however, vole survival was lowest in the unit with 8 years of rest, highest in the unit with 3 yrs of rest, and intermediate in the unit with only 1 yr of rest. Our results indicated that the current grazing program on the refuge (2-yr rest-rotation) may not permit vole populations to reach maximum abundance, and a density-dependent response of survival.

Birds, Grazing, and Restoration in Tall-Willow Riparian Communities of Central Montana

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Using birds as a tool, the Avian Science Center has been monitoring the effects of several riparian restoration and grazing management projects in Montana. In 2001 and 2003 we surveyed bird populations in tall-willow riparian habitats, primarily east of the continental divide. The goal of this project was to collect and develop information on avian species responses to riparian conditions, to identify the most effective techniques for active riparian management and restoration and the conservation of avian habitats. Tall-willow community types are important avian habitat on east-side forests, and are strongly impacted by grazing practices. Information on changes in vertical structure and cover of shrub layers is especially beneficial in managing these important riparian community types. We surveyed 36 sites on the four participating National Forests; grazed and ungrazed tall-willow riparian sites were categorized based upon the degree of physical evidence of grazing at the site. Although an overall effect of grazing can be clearly seen, important riparian bird species reacted differently to various structural changes. These results, together with ongoing collaborative efforts aimed to enhance the condition of riparian areas, will be used to help develop habitat models, decision support tools, and facilitate adaptive management. We hope this kind of collaboration will continue in more areas in the future.

Habitat Comparisons of Historically Stable and Less Stable Bighorn Sheep Populations

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Management of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis*) focuses on 1) population demographics, 2) immunological state, and 3) habitat characteristics. Demographic targets have been identified for successful populations. Habitats suitable for bighorn sheep have also been identified, and bighorn sheep population response to immunological stressors has been documented. Research has identified domestic sheep (*Ovis aries*) as a potential source of pneumophilic bacteria to bighorn sheep. However, not all bighorn die-offs are attributed to contact with domestic sheep. Limited research has documented how habitat differences between stable and less stable bighorn populations influences their success. Understanding these habitat differences may help explain how habitat contributes to bighorn population stability. The purpose of this study is to evaluate differences in spatial, vegetative, and geographic habitat characteristics of summer and winter ranges between historically stable and less stable bighorn sheep populations that occupy rangeland and open forest habitats in Montana in the presence of domestic sheep. Habitat variables will

be evaluated for two summers in summer and winter ranges of two bighorn sheep populations in Montana, in both their entire seasonal ranges and areas identified as foraging habitat. Land cover, slope, aspect, elevation, solar radiation index, and distance to escape terrain will be quantified in each habitat using a Geographic Information System (GIS). Field sampling will be used to determine shrub canopy cover, frequency of graminoids and forbs, and horizontal visibility of each habitat. Habitat characteristics of historically stable and less stable populations will be compared. Preliminary results will be presented.

Influence of Climate And Density on Fluctuating Asymmetry in Elk Antlers

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Antler size and symmetry can be an excellent indicator of individual fitness and social rank among North American elk (*Cervus elaphus*). When environmental conditions are favorable elk allocate resources to antler development over body weight to increase secondary sexual traits and enhance reproduction. Research indicates that size and fluctuating asymmetry (FA), the measure of random deviations from perfect bilateral symmetry, of elk antlers due to poor nutritional condition is a result of a tradeoff between body size and antler size. Using antler measurements (n = 2521), collected at the Gardiner Montana hunter check station by Montana Fish, Wildlife, and Parks (MTFWP) we tested two hypotheses expected to drive antler characteristics in elk. Our first hypothesis is that extreme climatic conditions (heavy snow and drought) in the northern Yellowstone area have altered the nutritional condition of elk, and thus FA. Second, we hypothesized that the occurrence of FA in elk antlers is associated with elk density where higher density of elk increases FA because of food-limitation. To test these hypotheses, we used mixed-effects time-series model of FA expressed as a function of climate covariates and elk density from winter aerial surveys. Our preliminary results support our hypotheses that harsh environmental conditions coupled with high elk densities influence the occurrence of FA in elk antlers. These results provide MTFWP with useful information on the effects of climate and density on antler characteristics of elk, an important big game species.

Short-Term Effects of Timber Harvest and Weather on Goshawk Reproduction

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Nesting habitat of the northern goshawk (*Accipiter gentilis*) in North America has been associated with the amount of mature, closed-canopy forest in the nesting area. However, few studies have experimentally tested the effects of timber harvest on goshawk reproduction. We studied the effects of clearcutting within the 170-ha nesting territory on reoccupancy and nesting success for 2 yr following disturbance. We also examined the effects of winter and

spring weather on goshawk reoccupancy and nesting success. We used classification trees to relate goshawk reproduction to habitat and weather variables. Classification trees showed that timber harvest did not affect goshawk territory reoccupancy as long as the 170-ha area surrounding the nest contained > 39 percent potential nesting habitat following harvest. However mean (SD) proportion of habitat remaining in reoccupied territories was 0.57 (0.16) in yr 1, and 0.58 (0.19) in yr 2. Increased nesting success was related to mean April daily precipitation <0.3cm and mean January maximum daily temperature >0.7 °C. In the short term, goshawks are more likely to attempt nesting in territories after disturbance if > 39 percent of their territory is left in potential nesting habitat. However, our models suggest that once goshawks attempt nesting, nesting success is more likely to be a function of winter and spring weather. We recommend leaving >50 percent potential nesting habitat within territories to increase the probability of reoccupancy.

Estimating the Natal Origins of Migratory Golden Eagles Using Stable-Hydrogen Isotopes

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The difficulty in determining geographic origins of migratory birds and identifying their regional, source populations has limited researchers in better understanding the migratory ecology of many North American species. Species such as the Golden Eagle (*Aquila chrysaetos*), are widely distributed and well studied on their breeding grounds in a few areas of the lower 48, as well as in Denali National Park, Alaska. However, there is still much to be learned in the area of their migratory and wintering ecology. Currently, there is a need for more study of this species in Western North America. Recent point count analysis show a significant 10 year decline in the number returning spring migrant Golden Eagles counted annually in Alberta, Canada. In 2004 and 2005, Raptor View Research Institute (RVRI) sampled feathers from 22 fall migrant hatch-year (HY) Golden Eagles 12 and 10, respectively, captured along the Rocky Mountain Front (RMF) in west-central Montana. We analyzed feathers using stable-hydrogen isotope analysis; specifically we looked at deuterium a stable isotope found in hydrogen. Numerous researchers have recently described the use of this technique as a means of deciphering the breeding origin of many migratory avian species. By analyzing feathers collected from unknown origin migrants, we set out to answer three primary questions. First, what latitude did the eagles originate from? Second, are there distinct temporal patterns of migratory movements annually, e.g., leap-frog or chain migration? Third, could we identify regional source populations?

Effects of Residential Development on Avina Communities and Individual Species in Quaking Aspen: the Importance Of Habitat Conservation on Private and Public Land

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It is a generally held tenet that habitat fragmentation and loss are primary threats to biodiversity. However, little is known about how residential development affects ecosystems, avian populations or individual species. Quaking aspen (*Populus tremuloides*), a species in decline, covers only 1 percent of the forested landscape in the Rocky Mountains but is nevertheless an important habitat for avian biodiversity. We studied the effects of low- and medium-density housing (< 2 houses/ ha and 2-5 houses/ ha, respectively), termed residential development, on bird communities and species using aspen habitat during the breeding season. Overall, residential development affected bird community composition at fine scales (250 -500 m spatial extents). These effects were best explained by multiple regression models containing variables from multiple spatial scales. Based on community composition results, patch size and percent aspen in the landscape were the habitat variables most influential to bird habitat selection. However, analysis of individual species abundances indicated that residential development had direct effects on individual species' abundances. This study's most important contribution to conservation efforts was the clear identification of scales relevant to land managers and residential development. These results suggest that future conservation efforts should focus on both private and public lands.

A Proposal for Studying Wetlands in The Face of Shifting Agricultural Practices, Energy Development, and Hydrologic Patterns

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Management of migratory birds in Western North America, especially those dependent on wetlands, are facing growing pressure on their habitat from increased biofuels production, oil and gas development, climate change, and especially potential shifts out of Conservation Reserve Program (CRP) grasslands. All these are affecting the hydrology of Montana wetlands, especially in the prairie pothole landscapes of the Northern and Eastern part of the state. An integrated understanding of the geohydrology and ecology of such wetlands is needed to understand, predict, and manage linkages between geohydrology and aquatic ecosystems and the response of wetland habitat to climatic and management actions. In Sheridan County, alone, there are over 1000 active and abandoned oil wells, and exploration

and production wastes from many of these wells have resulted in reduced water quality in adjacent wetlands. These issues are exceedingly complex, and we have proposed an ambitious project of interdisciplinary research to begin to understand the complexities. This project examines the following questions posed by Eastern Montana and Western North Dakota natural resource managers: 1) Are the brine plumes from oil wells in the Medicine Lake watershed affecting wetlands at Medicine Lake National Wildlife Refuge and the Northeast Montana Wetland Management District? And, are environmental effects from wells drilled in the past (using lined reserve pits) different than effects from the older, abandoned wells (that used unlined reserve pits)? 2) How will conversion of CRP lands back into crop and biofuels production affect groundwater gradients in refuge and Wetland Management District wetlands? 3) What effect will changes in hydrology due to CRP conversion have on brine plume movement? and 4) How representative are the environmental characteristics and issues of the Medicine Lake watershed compared with those at the broader regional scale? To what extent can a broader geographic context help inform management at the local scale?

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