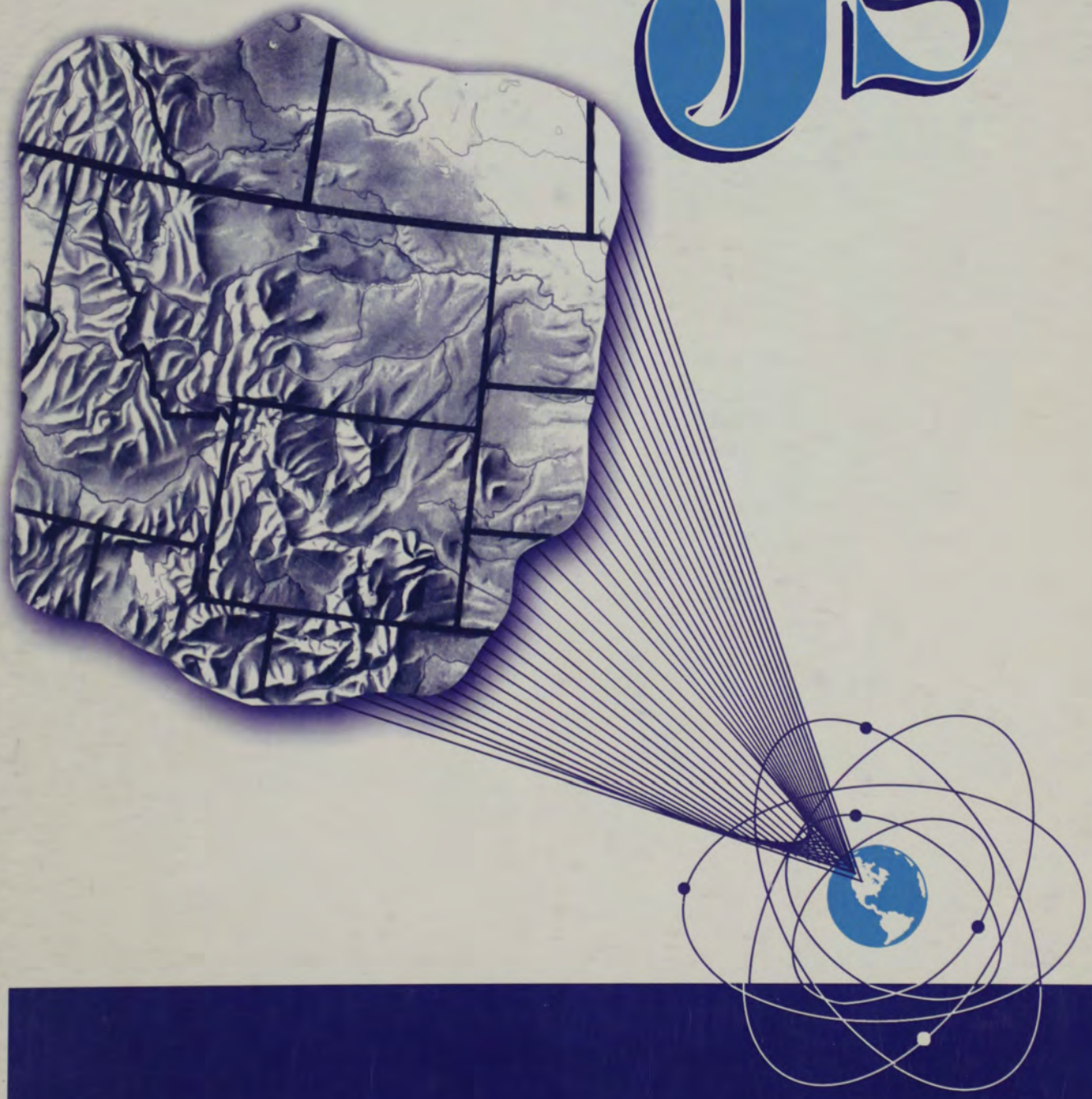
Intermountain Journal of Sciences

(ISSN 1081-3519)

Vol. 13, No. 4 - 2007

IJS



INTERMOUNTAIN JOURNAL OF SCIENCES

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

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

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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ISSN #1081-3519

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Financial Statement (1/01/07 - 12/31/07)

	Balance 01/01/07		**$3,344.25**
Income:			
Regular Member		$120.00	
Library Subscriptions		$325.00	
International Member		$25.00	
	Subscriptions Total		$470.00
Page Charges			$8,110.00
Reprints			$1,066.28
Back Issue Sales			$80.00
Grant			$600.00
	Total Income		**$10,326.28**
Expenses:			
Layout and Printing			$11,752.85
Postage			$474.38
Office Supplies			$382.55
P. O. Box Rent			$92.00
Misc. Fees			$54.40
Reprints and Layout			$213.32
Website Hosting and Maintenance			$136.80
Photocopy			$6.99
	Total Expenses		**$13,113.29**
	Balance 12/31/07		**$557.24**

Fred Nelson, Business Manager

Editorial Review Policy

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

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

Three hard copies of the submitted manuscript, with copies of the "Guidelines and checklist for IJS referees" attached are forwarded to the appropriate Associate Editor. The Associate Editor retains one 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)

Diatom Indicators of Climate Change in Glacier National Park

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Abstract

Permanent slides in the Montana Diatom Collection representing periphyton samples collected during the 2007 field season and samples collected in prior years were examined to determine the distribution and abundance in and near Glacier National Park of two diatom species: *Didymosphenia geminata* and *Distrionella incognita* (Kingdom Plantae, Phylum Bacillariophyta). *Didymosphenia geminata* ("didymo", "rock snot") is becoming a nuisance in the west and will probably increase in abundance in response to global warming and reduced stream flows. *Distrionella incognita* ("glacier gold") is a rare glacial relict species and will probably decrease in abundance in response to predicted climate change. *Didymosphenia* has been widely distributed and locally abundant in the Park since 1976. Large populations of this diatom have been recorded in all three of the Park's major drainage basins: Pacific, Atlantic, and Hudson Bay. Samples collected in 2007 from Duck Lake, Kintla Lake, and St. Mary Lake document the first large populations of *Distrionella* to be recorded in North America. The genus *Distrionella* is known only from cold, mountainous, and glaciated regions of the world.

Key words: biodiversity, climate change, didymo, *Didymosphenia*, *Distrionella*, diatoms, glacier gold, Glacier National Park, global warming, invasive species, relict species, rock snot

Introduction

A 3-yr survey of diatom (Kingdom Plantae, Phylum Bacillariophyta) biodiversity in Glacier National Park was initiated during the 2007 field season. Supplemented by records from 1976-2006, the survey will produce a checklist of diatom species from the Park with photographic documentation of voucher specimens. Distribution of species throughout the Park and their relative abundance in various habitats will also be recorded. The survey was predicated on three assumptions: 1) aquatic habitats of Glacier support diverse associations of largely native diatom species; 2) diatom flora of Glacier National Park will include species that are endemic to the region and new to science; and 3) diatom flora of Glacier National Park will include species that are sensitive to global warming, atmospheric deposition, and other ecological perturbations.

Two diatom species in particular, both presumably native to the Park, have promise as indicators of environmental change—one as an "increaser" and the other as a "decreaser".

Didymosphenia geminata ("didymo," "rock snot"; Fig. 1) is an aggressive invader that forms conspicuous growths on stream bottoms (Fig. 2), which may reach nuisance levels for public recreation (Spaulding and Elwell 2007). Growths of *D. geminata* have been known to alter food web structure and stream ecosystem function, degrade water supplies, modify stream hydraulics, and strain regional and national economies through impacts on fisheries, tourism and hydropower (U. S. Environmental Protection Agency 2007).

Distrionella incognita or "glacier gold" (Fig. 3) is a relatively rare diatom and a glacial relict species. Until recently, *D. incognita* had been reported only from lakes in the British Isles and European Alps (Krammer and Lange-Bertalot 1991). In 2005 a team of researchers reported small

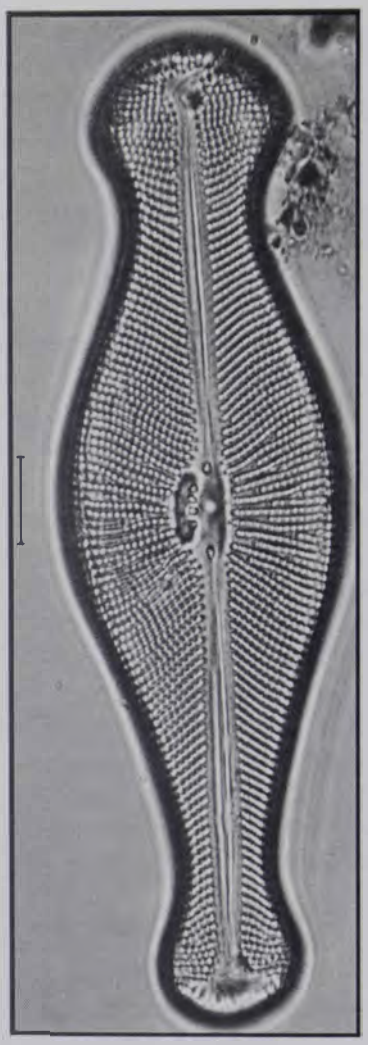

Figure 1. Photomicrograph of *Didymosphenia geminata* (rock snot) from Two Medicine Creek, Glacier National Park. Scale bar = 10 µm.

Figure 2. Rocks covered with *Didymosphenia geminata* (rock snot) in Two Medicine Creek below Running Eagle Falls, September 2007.

Figure 3. Photomicrograph of *Distrionella incognita* (glacier gold) from Kintla Lake, Glacier National Park. Scale bar = 10 µm.

populations of *D. incognita* from several streams that drain the Canadian Rockies Ecoregion in northwestern Montana (Morales et al. 2005). These researchers speculated that much larger populations of *D. incognita* might be found in lakes of Glacier National Park.

Sample Sites

Forty-six periphyton samples were collected under various projects at 20 sites from 1976 through 2006, and another 68 samples were collected at 68 new sites in 2007 (Fig. 4). Slides representing all of these samples have been deposited in the Montana Diatom Collection (maintained by the author in Helena, Montana) and will be included in the biodiversity study.

The 88 total sites included 33 standing waters and 55 flowing waters. Forty-two sites were west of the Continental Divide (Pacific drainage), 28 are north of the Divide (Hudson Bay drainage), and 18 were east of the Divide (Atlantic drainage). All sites occurred along motor routes or within a 1-day

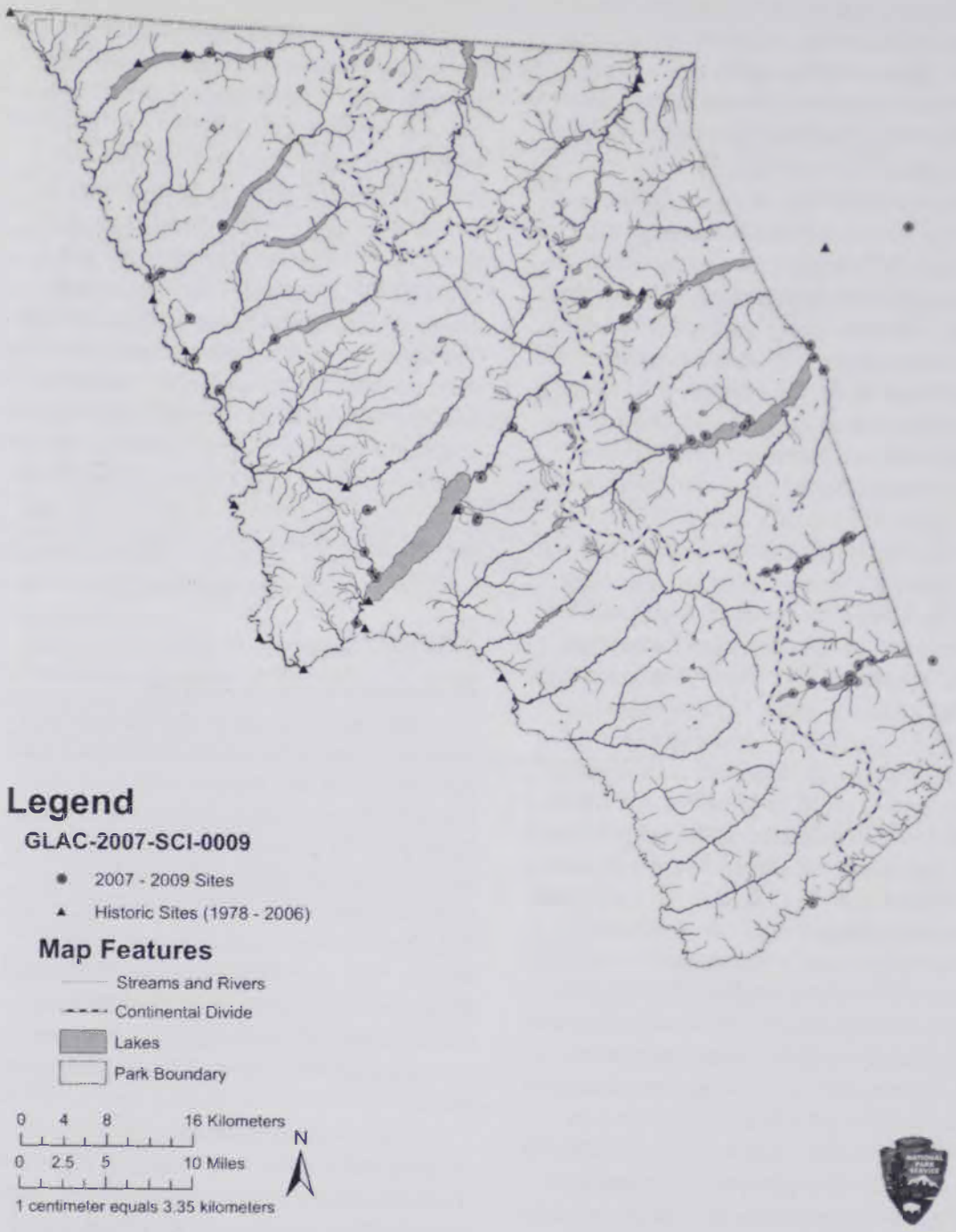

Figure 4. Diatom biodiversity sampling stations in Glacier National Park, 1976-2007.

hike from a trailhead. Most were front country sites near the lower ends of the Park's major catchments. Two sites that were sampled in 2007—Duck Lake and Lower Two Medicine Lake—and one pre-2007 site—Swiftcurrent Creek near mouth—are located near the Park but outside the Park boundary.

Methods And Materials

2007 Samples

Periphyton samples were collected following Montana Department of Environmental Quality Standard Operating Procedure 12.1.2 for water quality monitoring, available at www.deq.state.mt.us/wqinfo/monitoring/SOP/sop.asp. This is a targeted

multihabitat method in which available substrates (rocks, wood, sediment, mosses and higher plants) were sampled in proportion to their importance at a site, and conspicuous algal growths (filaments and colonies) were also selected for sampling. Samples from various substrates and of conspicuous algal growths were combined in a single sample container. All samples were collected within wading distance from stream banks or lake shores. Samples were preserved with Lugols (IKI) solution and kept dark during transport and storage. In the lab samples were treated with concentrated sulfuric acid, potassium dichromate, and hydrogen peroxide to remove organic matter. I prepared three permanent slides of randomly strewn diatom frustules in Naphrax® and accessioned them into the Montana Diatom Collection. The slide with the most even distribution of frustules on the cover glass was chosen for analysis. I stored the remaining cleaned diatom material in glass vials for future SEM work and for making more slides if necessary.

Because of its large size, *Didymosphenia geminata* could be identified and counted under low magnification (100X). For each slide, I scanned the entire 18-mm x 18-mm cover glass and counted all valves of *D. geminata*. Each diatom cell or frustule consists of two valves, one fitting inside the other like an old-fashioned pillbox. The number of valves divided by 2 equals the number of cells. Because samples were representative of substrates and conspicuous growths and because slides are prepared to achieve as even a distribution of diatoms as possible, this method will approximate relative abundance of *Didymosphenia* at a site compared to other sites.

For *Distrionella incognita*, a much smaller diatom, I scanned each slide at 400X to determine if the taxon was present. If present a proportional count of 600 valves was conducted with a 1000X oil immersion objective (1.4 NA) on a Leica DMLB2 research microscope. In this count, valves of *D. incognita* were counted versus valves of all other species. This method also approximated relative abundance of *Distrionella* at a site compared to other sites.

Pre-2007 Samples

Pre-2007 samples were collected in the same manner as 2007 samples except that samples from Lake Winona, Lake McDonald, and Swiftcurrent Lake were taken at a depth requiring a wet suit and SCUBA gear. Pre-2007 samples were processed in the same manner as 2007 samples except that only one or two slides were prepared, cover glasses were variable in size, various mounting media (Carmount®, Hyrax®, Naphrax®) were used, and cleaned diatom material was not retained. Slides made from pre-2007 samples were scanned at 100X and 400X to determine the presence of *Didymosphenia geminata* and *Distrionella incognita*, respectively. If *Distrionella incognita* was present, a 600-valve count was performed at 1000X.

Results

Didymosphenia geminata

Didymosphenia geminata was present in 36 of 46 pre-2007 samples (Table 1). Earliest records of this species were from the North Fork and Middle Fork of the Flathead River in 1976. Numerous valves of *D. geminata* were observed on slides made from samples collected in 1976 at Polebridge and Big Creek on the North Fork and from the Middle Fork at its mouth. At pre-2007 sites, *D. geminata* was present in 35 of 39 samples collected from flowing waters and in one of seven samples collected from standing waters.

D. geminata was found in 36 of the 68 samples collected in 2007 (Table 2, Fig. 5). It occurred in 30 of 41 flowing waters (73%) and in 6 of 27 standing waters (22%). Large populations (> 200 valves) of *Didymosphenia geminata* were recorded in all three of the Park's major drainage basins: Atlantic, Pacific, and Hudson Bay. Lake McDonald was the only standing water that supported a large population of this diatom. Sites that supported conspicuous growths of this species (as in Fig. 2) were all exposed to direct sunlight in openings of the forest canopy (field notes). Several of these locations are flowing waters below waterfalls or lake outlets. Smaller

Table 1. Presence or absence of *Didymosphenia geminata* in periphyton samples collected in or near Glacier National Park from 1976 through 2006. Water body names followed by an asterisk are the author's names for water bodies not named on USGS topographic maps.

Water Body and Location	Sample Year(s)	No. Samples	*Didymosphenia*
North Fork Flathead River at Canadian Border	1976	1	0/1
North Fork Flathead River at Polebridge	1976	1	1/1
North Fork Flathead River at Big Creek	1976	1	1/1
Middle Fork Flathead River at mouth	1976	1	1/1
North Fork Flathead River near Columbia Falls	1978-1980, 2001-2003	4, 3	3/4, 3/3
Middle Fork Flathead River near West Glacier	1978-1980, 2001-2003	4, 3	4/4, 3/3
Swiftcurrent Creek near mouth	1978-1980	4	4/4
Kintla Lake near inlet	1979	1	0/1
Kintla Spring* to Kintla Lake about half way up north shore	1979	1	0/1
Belly River at Threemile Camp	1980, 1996	2	1/1, 1/1
Lake McDonald near Apgar	1993	1	1/1
Belly Spring Brook* alongside Belly River near Threemile Camp	1996	1	0/1
Middle Fork Flathead River below Nyack Creek, downwelling area	1997	4	3/4
Middle Fork Flathead River below Nyack Creek, neutral VHG	1997	4	4/4
Middle Fork Flathead River below Nyack Creek, upwelling area	1997	4	4/4
Lake Winona	1999	1	0/1
Lake McDonald at mouth of Sprague Creek	1999	1	0/1
Swiftcurrent Lake at boat ramp near picnic area	1999	1	0/1
Weeping Wall, Logan Pass	1978	1	0/1
Camas Creek 250 yards above Inside North Fork Road	2006	2	2/2

numbers of *D. geminata* were recorded at some higher elevation sites, e.g. Siyeh Creek, and in presumably near pristine waters, e.g., Wild Creek.

Distrionella incognita

Among pre-2007 samples, I detected *D. incognita* in the North Fork Flathead River near Columbia Falls and in the Belly River at Threemile Camp, where it accounted for 7 percent and 1 percent of diatom valves, respectively. These specimens may have originated in any one of several upstream lakes. None of the pre-2007 lake samples included this species.

In 2007 large populations of *Distrionella incognita* (> 200 valves) were recorded in Kintla Lake, St. Mary Lake and Duck Lake (Table 2, Fig. 6) that confirmed this diatom as primarily a species of large lakes. Smaller populations were found in Swiftcurrent Lake, Lake Josephine, and Bowman Lake. Among streams, the largest number of valves (104) was recorded in the St. Mary River below St. Mary Lake. Much smaller numbers were recorded in Bowman Creek below Bowman Lake, Quartz Creek near its mouth, and in McDonald Creek below Lake McDonald. The presence of *D. incognita* in Quartz Creek suggested that it also occurred in one or both of the Quartz Lakes. Although it was not found in the sample collected from Lake McDonald, its presence in lower McDonald Creek suggested that it was present there also.

Discussion

Didymosphenia geminata is likely native to Glacier National Park. It was first reported from Montana in 1929 when C. J. Elmore found *Gomphonema geminatum* (Lyngbye) Agardh in collections from Flathead Lake (Prescott and Dillard 1979). Records derived from slides deposited in the Montana Diatom Collection indicated that this taxon is widely distributed in the Pacific Northwest (Bahls 2004). Because of its large size, *Didymosphenia geminata* is often missed during diatom proportional counts, which are conducted at high microscope magnifications. Therefore, this taxon

Table 2. Total number of Didymosphenia geminata valves per slide and number and percent of Distrionella incognita valves in counts of 600 diatom valves in periphyton samples collected in or near Glacier National Park in 2007. Water body names followed by an asterisk are the author's names for water bodies not named on USGS topographic maps.

Water Body and Location	*Didymosphenia* No. Valves	*Distrionella* No. Valves	*Distrionella* %
Fish Creek at campground	19		
Kintla Lake		280	46.7
Kintla Spring Pool* on trail between upper and lower Kintla Lakes			
Kintla Creek above upper Kintla Lake			
Two Medicine Lake (north shore)	18		
No Name Creek* below No Name Lake and Twin Falls	373		
Upper Two Medicine Lake (east end)			
Two Medicine Spring* at N. Shore Two Medicine Lake Trail			
Paradise Creek at mouth (at Two Medicine Lake)	37		
Paradise Pond* near Paradise Cr. on S. Shore Two Medicine Lake Trail			
Two Medicine Creek below Pray Lake at Two Medicine Campground	116		
Lower Two Medicine Lake near reservation boundary			
Two Medicine Creek below Running Eagle Falls	99		
Paradise Spring Brook* (outlet from Paradise Pond*)	6		
Duck Lake		227	37.8
Swiftcurrent Lake west shore at trail		22	3.7
Cataract Creek above Lake Josephine	7		
Josephine Wetland* along boardwalk at head of Lake Josephine			
Lake Josephine, southeast shore near boat dock	3	8	1.3
Sherburne Spring Seep* at head of Lake Sherburne near Cracker Flats			
Allen Creek at Cracker Lake trail	2		
Canyon Creek near mouth on Cracker Flats			
Redrock Lake at trail	6		
Bullhead Lake, north shore near trail and constriction	2		
Windmaker Creek* at trail near Bullhead Lake	5		
Swiftcurrent Creek below Wilbur Creek and above campground	7		
Logging Seep* next to Logging Lake trail at upper edge of 1988 Burn			
Logging Lake at Logging Lake Campground			
Logging Creek near upper edge of 1988 Burn	890		
Quartz Creek at Quartz Creek Campground	231	1	0.2
Hidden Meadow Lake near lone pine			
Bowman Lake southwest shore near ranger station		6	1.0
Bowman Creek 0.85 miles above Inside North Fork Road	429	18	3.0
Akokala Creek below Inside North Fork Road	39		
Logging Creek east branch at Logging Creek Campground Unit 2	189		
Bear Creek at US Highway 2 below Autumn Creek and Skyland Creek	939		
Atlantic Creek below Atlantic Falls	504		
Medicine Grizzly Lake near outlet			
Atlantic Pond* on trail below Medicine Grizzly Lake			
Amphitheater Creek* above North Fork Cut Bank Creek Trail	10		
Cut Bank Pond* along North Fork Cut Bank Creek Trail			
Eagle Plume Creek* near mouth	2		
Kupunkamint Creek* above North Fork Cut Bank Creek Trail			
North Fork Cut Bank Creek at Cut Bank Campground	42		
Saint Mary River at Saint Mary Campground footbridge	235	104	17.3
Divide Creek above Saint Mary townsite			

Table 2. cont.

Water Body and Location	*Didymosphenia* No. Valves	*Distrionella* No. Valves	*Distrionella* %
Wild Creek below Glacier National Park Boundary	5		
Rose Creek at Rising Sun	232		
Saint Mary Lake at Golden Stairs		438	73.0
Lost Lake on Going-to-the-Sun Road			
Siyeh Creek above Siyeh Bend	20		
Siyeh Seep* along Going-to-the-Sun Road at Siyeh Bend			
Virginia Creek below Virginia Falls	2		
Dusty Star Creek* above trail to Virginia Falls			
Saint Mary River above Saint Mary Falls	266		
Baring Creek below Baring Falls	2		
Howe Creek at trail below outlet from Lower Howe Lake			
Lower Howe Lake			
Howe Creek at Inside North Fork Road			
Fern Creek at Inside North Fork Road	2		
Lake McDonald at glacier exhibit on GTTS Road above Sprague Creek	207		
Avalanche Creek at mouth	2		
McDonald Creek above Avalanche Creek	3		
Johns Lake			
Johns Fen* south of Johns Lake on Johns Lake Loop Trail			
Fish Lake			
Sprague Creek at Fish Lake Trail			
McDonald Creek near mouth above Quarter Circle Bridge	10	2	0.3

is probably much more widespread than reported.

Based on pre-2007 samples, *Didymosphenia geminata* was widely distributed in and near Glacier National Park. It occurred in 78 percent of all samples and in 90 percent of flowing water samples collected from 1976 through 2006. Slides made from samples collected in 1976 from the lower North and Middle Forks of the Flathead River suggest that both rivers supported heavy growths of *Didymosphenia geminata* that year. Samples collected in 2007 indicated that *Didymosphenia geminata* remains widely distributed and locally abundant in Glacier National Park.

Available data were not sufficient to determine whether populations of *D. geminata* were increasing, decreasing, or stable in the Park. Elsewhere, this species is rapidly expanding its range and becoming a nuisance (U.S. Environmental Protection Agency 2007). In the United States, streams with higher base flow index at higher elevations in cooler climates have the highest probability of *D. geminata* presence (Kumar et al. unpublished data). The base flow index is base flow—the component of stream flow attributed to groundwater discharge—computed as a percentage of total stream flow. Preliminary modeling suggests that mean temperature of the warmest calendar quarter and the base flow index are the two best predictors of potential suitable habitats for *D. geminata* (Kumar et al. unpublished data).

In Glacier and elsewhere in the Canadian Rockies Ecoregion, warmer temperatures, shrinking glaciers and lower stream flows (Rood et al. 2005, Fagre 2007) may favor growth of *D. geminata* over the long term. Short-term cycles of drought may also be a factor. In the summer of 2007, both Flathead and Glacier Counties were in the midst of "severe drought" (Montana Natural Resources Information System 2007). Some effects of global warming and drought in the Park have been lower peak runoff, lower base flows, and disappearing streams (Fagre 2007, Jamison 2007). The lack of substrate-scouring flows in the spring may allow

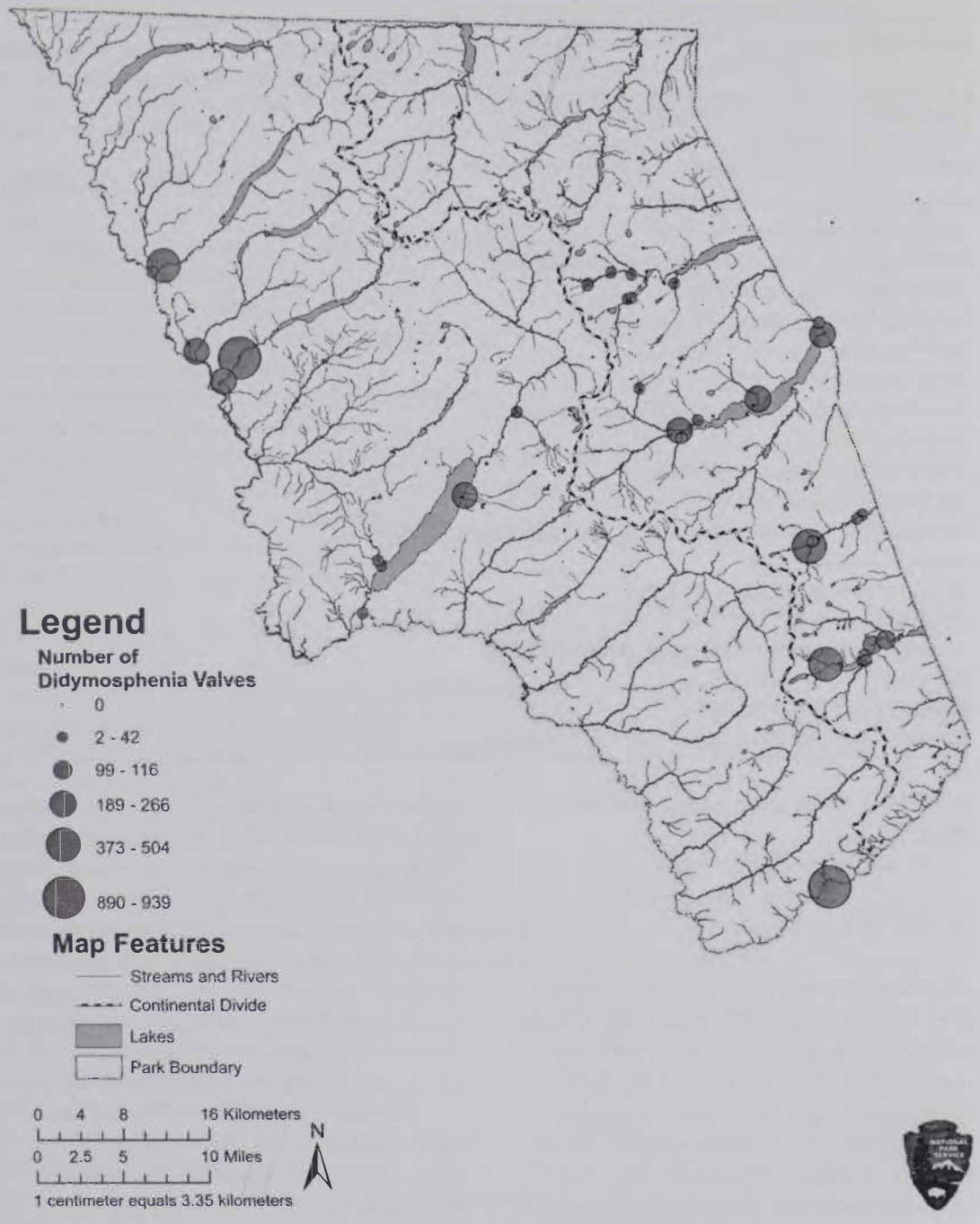

Figure 5. Distribution and relative abundance of *Didymosphenia geminata* (rock snot) in Glacier National Park, 2007.

Didymosphenia colonies to persist from one year to the next. Lower base flows may concentrate nutrients and elevate summer water temperatures to levels that are more amenable to the growth of *Didymosphenia*. Given current drought conditions and local abundance of *Didymosphenia*, and given projected climate changes and observed hydrologic trends in the Park, populations of *Didymosphenia* will probably increase in the future.

Samples from Kintla, Duck, and St. Mary Lakes were the first records of large populations of *Distrionella incognita* in

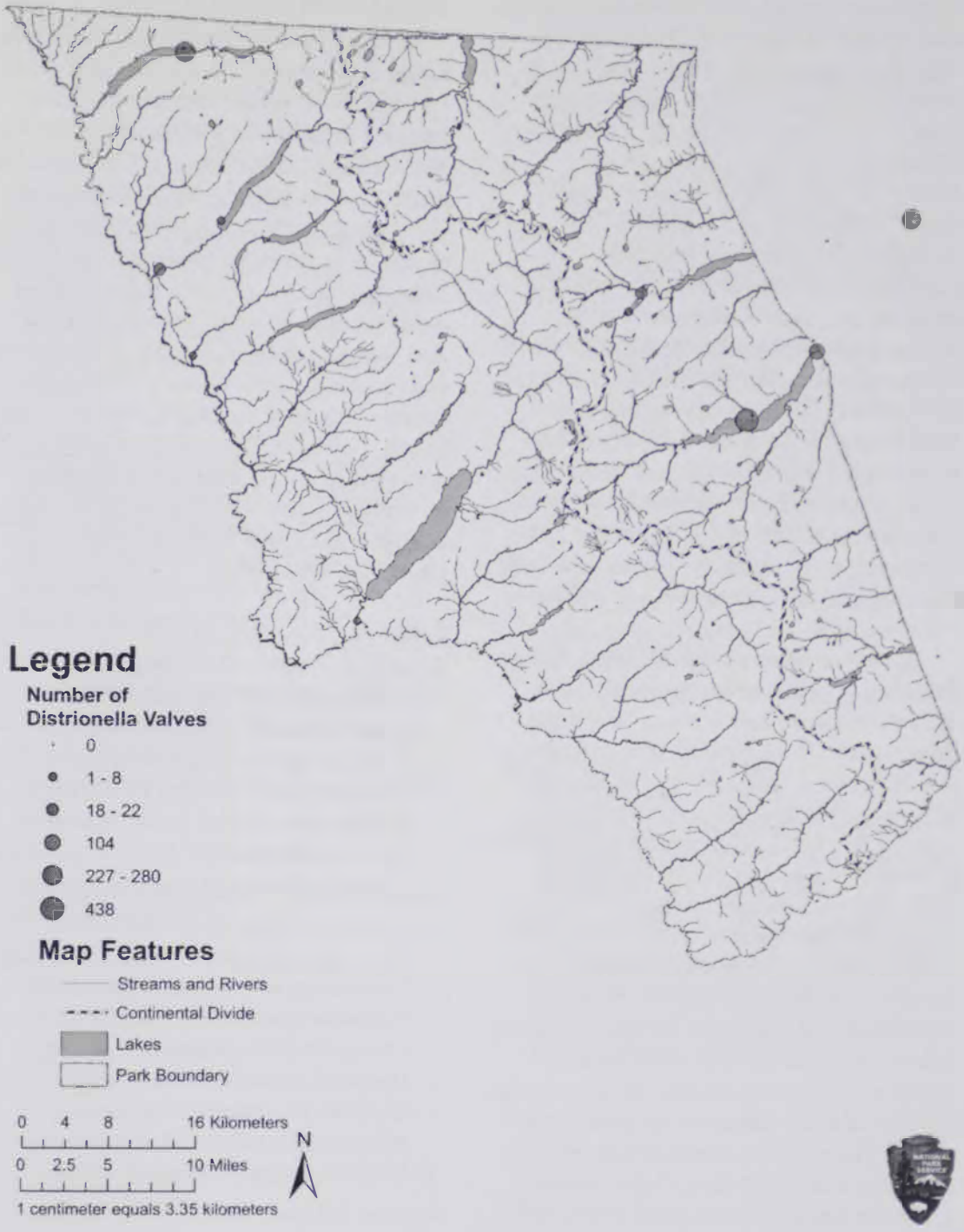

Figure 6. Distribution and relative abundance of *Distrionella incognita* (glacier gold) in Glacier National Park, 2007.

North America. These samples confirm that the preferred habitat for *D. incognita* is large glacially scoured lakes in the Canadian Rockies Ecoregion. Smaller glacial lakes, e.g., Josephine and Swiftcurrent lakes, also support this diatom. Smaller numbers of this diatom have been recorded in streams (Morales et al. 2005, this study). As with the St. Mary River below St. Mary Lake, most if not all individuals of this species that have been recorded in streams probably originated in upstream lakes.

Distrionella incognita and other *Distrionella* species are restricted in their

distribution to cold, mountainous, and glaciated regions of the world: the European Alps (Reichardt 1988), the Isle of Mull in Scotland (Williams 1990), Subantarctica (Van de Vijver et al. 2000), the Kerguelen Islands (Reichardt and Lange-Bertalot 1990), and the southern Andes in South America (Rumrich et al. 2000). Given its range and autecology, populations of *Distrionella* in Glacier National Park will probably decrease in response to global warming and projected hydrologic trends. *Periphyton* and other monitoring conducted by the Rocky Mountain Inventory and Monitoring Network (ROMN) of the National Park Service's Vital Signs Program, available at http://science.nature.nps.gov/im/units/romn, may help elucidate population trends and contributing factors for both *Distrionella* and *Didymosphenia* in Glacier National Park.

Common names are useful in that they help the lay public relate to organisms in our environment. Few diatoms have common names. "Rock snot" is very descriptive and evidently coined by someone who has experienced large fresh colonies of *Didymosphenia* first hand. *Distrionella* did not have a common name, so I gave it one: glacier gold. This name is appropriate for a variety of reasons. The "glacier" part refers both to Glacier National Park, where large populations of this species were first found in North America, and to the diatom's preferred habitat, which is literally in the wake of glaciers. This is true not only of *D. incognita* but also of other species in the genus *Distrionella*. The periphyton assemblage on rocks along the shore of St. Mary Lake, where I found the largest percentage of *Distrionella* (73%), had a bright golden color. Coincidentally, I collected the St. Mary Lake sample at a place along the Going-To-The-Sun Road called Golden Stairs, which is named for a distinctive limestone formation. The word "gold" also conveys a sense of value and rarity—*D. incognita* is a rare diatom, at least in the conterminous United States. Finally, glacier gold is a reference to the "mother lode" (primary *in situ* deposit) of this diatom in North America: Glacier National Park.

Acknowledgements

This report would not be possible without the generous support of an anonymous donor. I wish to thank several employees of the National Park Service for their help with this project: Tara Carolin and Jack Potter provided administrative support; Billy Schweiger provided maps; my Helena neighbor Bob Adams took time on a very busy day at Many Glacier Ranger Station to give me a safety briefing on short notice. Thanks to numerous Park staff and campground hosts for their courtesy and assistance. Erich Weber and Mike and Shelley Pasichnyk assisted in the field. Gary Dusek, David Stagliano, and two anonymous reviewers provided constructive comments on the manuscript. The 2007 samples were collected under NPS research permit GLAC-2007-SCI-0009.

Literature Cited

Bahls, L. L. 2004. Northwest Diatoms: A Photographic Catalogue of Species in the Montana Diatom Collection, with Ecological Optima, Associates, and Distribution Records for the Nine Northwestern United States. Volume 1. *Hannaea*, Helena, MT

Fagre, D. B. 2007. Adapting to the reality of climate change at Glacier National Park, Montana, USA. Pages 221-235 in Proceedings of The First International Conference on the Impact of Climate Change on High-Mountain Systems, Bogota, Colombia, November 21-23, 2005. *Instituto de Hidrologia Meteorologia y Estudios Ambientales* IDEAM, Bogota, Colombia. 294 pp.

Jamison, Michael. 2007. Glacier National Park's namesakes shrinking, streams drying up. Helena Independent Record, Monday, 15 October 2007.

Krammer, K. and H. Lange-Bertalot. 1991. Bacillariophyceae, Part 2, Volume 3: Centrales, Fragilariaceae, Eunotiaceae. In Ettl, H., J. Gerloff, H. Heynig, and D. Mollenhauer (eds.), Freshwater Flora of Middle Europe. Gustav Fischer Publisher, Stuttgart.

Kumar, S., S. A. Spaulding, T. J. Stohlgren, K. Hermann, T. Schmidt, and L. Bahls. Draft manuscript. It is coming: Potential habitat distribution for freshwater diatom *Didymosphenia geminata* in the Continental United States. Target journal: Frontiers in Ecology and Environment.

Montana Natural Resources Information System. 2007. Montana County Drought Status (map). Available online at http://nris.mot.gov/drought/status/Oct07/drtstatus.pdf (accessed 7 November 2007).

Morales, E. A., L. L. Bahls, and W. R. Cody. 2005. Morphological studies of *Distrionella incognita* (Reichardt) Williams (Bacillariophyceae) from North America with comments on the taxonomy of *Distrionella* Williams. Diatom Research 20(1):115-135.

Prescott, G. W. and G. E. Dillard. 1979. A Checklist of Algal Species Reported from Montana: 1891-1977. Monograph No. 1, Montana Academy of Sciences, Supplement to the Proceedings, Volume 38.

Reichardt, E. 1988. *Neue Diatomeen aus Bayerischen und Nordtiroler Alpenseen.* Diatom Research 3:237-244.

Reichardt, E. and H. Lange-Bertalot. 1990 *Fragilaria germainii, eine zweite Fragilaria-Art mit diatomoiden Rippenstrukturen.* Pp. 203-209 in: *Ouvrage dédié à la Memoire du Professeur Henry Germain* (1903-1989) (M. Ricard & M. Coste, eds.), Koeltz Scientific Books, Koenigstein, Germany.

Rood, S. B., G. M. Samuelson, J. K. Weber, and K. A. Wywrot. 2005. Twentieth-century decline in streamflows from the hydrographic apex of North America. Journal of Hydrology 306(1-4):215-233.

Rumrich, U., H. Lange-Bertalot, and M. Rumrich. 2000. Diatoms of the Andes from Venezuela to Patagonia/Tierra del Fuego. Iconographia Diatomologica 9:1-673.

Spaulding, S. A. and L. Elwell. 2007. Increase in nuisance blooms and geographic expansion of the freshwater diatom *Didymosphenia geminata.* White Paper, U. S. Environmental Protection Agency. Available at www.epa.gov/region8/water/didymosphenia/.

U. S. Environmental Protection Agency. 2007. *Didymosphenia geminata*: A nuisance freshwater alga. Available online at www.epa.gov/region8/water/didymosphenia/ (accessed 4 December 2007).

Van de Viver, B., L. Denys, and L. Beyens. 2000. Fragilaria husvikensis sp. nov. (Bacillariophyceae), another species with transapical ribs from Subantarctica. Nova Hedwigia 70:537-550.

Williams, D. M. 1990. *Distrionella* D. M. Williams, nov. gen., a new araphid diatom (Bacillariophyta) genus closely related to *Diatoma* Bory. *Archive für Protistenkunde* 138:171-177.

Received 17 December 2007
Accepted 15 February 2008

Mercury in Mouse Hair: A Monitoring Tool for Environmental Exposure

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ABSTRACT

We determined mercury concentrations for soil and mouse hair from four Montana sites. Two of the sites associated with previous mining activity had elevated soil mercury concentrations. One site with an average total mercury concentration of 22.4 μg/g was > 200 times higher than concentrations reported for typical U.S. topsoils. Mean mercury concentrations of 4.5 μg /g and 5.1 μg /g were measured in the hair of mice living on the contaminated sites—five to six times higher than hair concentrations from mice captured at the other two sites. From the information collected during this study, monitoring of mercury levels in mouse hair could provide valuable data to assess either environmental exposure at contaminated sites or to establish environmental baseline data.

Key words: mercury, mouse hair, biomonitoring, bioindicators, mining

INTRODUCTION

The idea that small mammals could be used as monitors for environmental contamination is not new. In the 1980s Douglass (1984, 1989) and Skalski (1984) recommended that rodents be used for ecological monitoring. They pointed out that rodents are particularly useful because they are small, easy to handle, and spend their entire life cycle within a relatively small area, e.g., mines or urban sites. Mice also hold ecological importance in food chains because they are food for nearly all terrestrial and avian carnivores. Reynolds et al. (2006) recently reported that northern pocket gophers may be useful biomonitors of heavy metal (Pb, Cd, and As) contamination. Our investigation focused on the possibility of using mercury in mouse hair as an appropriate biomonitor for environmental mercury.

In biological materials mercury is often bound with sulfur in amino acids and proteins. Since it is comprised mostly of protein, hair has often been used to indicate mercury exposure in mammals including humans. Many studies have confirmed that people and mammals exposed to environments or foodstuffs contaminated with mercury accumulate mercury in their hair (Matsubara and Machida 1985, Kosatsky et al. 2000, Fortin et al. 2001; U.S. Environmental Protection Agency 1997). In human hair Kosatsky et al. (1985) found that participants who ate sportfish at least once/week had hair geometric mean mercury concentrations of 0.82 μg/g compared to 0.38 μg /g for those who ate sportfish < once/week. Fortin et al. (2001) found mercury concentrations of 30.1 μg/g in mink fur and 20.7 μg/g in river otter fur from James Bay Territory. Peterson and Madden (2006) reported using domestic pets as sentinel species by measuring heavy metals in hair.

Previous work on mercury concentrations in mouse hair was performed by Burton et al. (1977) who captured mice from four similar habitats in Utah. They found hair mercury levels in seven deer mice (*Peromyscus maniculatus*) from a rural site near Vernal, Utah, to average 0.31 μg/g, and in six mice from near Magna (the site of a copper smelter), Utah, to average 1.7 μg/g. However, mice captured from Bird and Badger Islands—two islands in the

Great Salt Lake—had much higher levels. Fourteen mice from Bird Island averaged 10.8 µg/g and eight mice from Badger Island averaged 7.8 µg/g. Burton et al. (1977) postulated that the higher concentrations in the island mice were caused from mercury found in brineflies that comprised a major part of the diet for these mice. They did not report soil concentrations.

Mercury levels in soils may vary widely depending upon the soil's origin. Warren et al. (1966) measured total mercury concentrations from 10-50 ηg/g (ppb) in soils unaffected by mineralization to concentrations as high as 10,000-20,000 ppb in immediate areas of mercury mineralization. The U. S. Geological Survey (USGS, 1970) assembled a large amount of data regarding the mercury content of various earth materials. In 2004 the USGS and the Geological Survey of Canada initiated pilot studies for the North American Soil Geochemical Landscape Project (Smith et al. 2005). They reported total mercury concentrations of 0.02-0.71 µg/g (ppm) in the soil A horizon at 260 sites across the United States with only six samples > 0.1 µg/g. Phelps and Buseck (1980) reported "background levels of mercury" in Yellowstone National Park soils that averaged 20 ppb with an anomaly threshold of 40-50 ppb.

We designed our study to determine whether deer mice living in areas with elevated soil mercury concentrations would show increased mercury in their hair compared to mice living in areas with lower soil mercury concentrations. We examined mercury levels in hair from mice captured at four sites in western Montana. Two sites, Silver and Trinity Creeks, were drainages with evidence of past gold placer mining. Another, the Comet mine site, was an engineered repository where mining waste materials had been buried, capped with a waterproof barrier and covered with topsoil. A ranch site near Cascade, Montana, had no history of mining activity. Waring and Waring fully described (2006) the Silver Creek, Trinity Creek, and Comet mine sites.

METHODS

Sampling areas of ~ 2 ha were established at each site. All soil and mice were sampled during the 2nd week of June 2003 along transects crossing the sampling areas. The soil sampling and lab procedure protocols were described by Waring and Waring (2006).

Mice were caught by placing 100 Sherman live traps in four parallel rows of 25 traps spaced at 10-m intervals. We inserted synthetic cotton for bedding and baited traps with peanut butter and oatmeal. Each animal was removed from a trap by emptying them into an unused bread bag. We removed a hair sample from the animal's back with scissors and placed it in a vial. Before release, we recorded species, sex, breeding condition, and weight of each animal. To avoid cross contamination, scissors were washed in distilled water and acid rinsed between samples. We placed sample vials on ice in a sampling cooler and returned to the laboratory.

Soil samples were obtained at 10- to 20-m intervals along transects crossing the sampling areas. Each sample was obtained at a depth of 10-20 cm using a spade to raise the soil and then obtaining the sample using a plastic spoon. We took care to sample only soil that had not contacted the shovel surface. For each soil sample location, a composite sample was obtained by combining eight sub-samples into a plastic bag. The sample was placed on ice in the cooler for transport to the laboratory where it was frozen until later analysis.

For hair analysis, samples were removed from the vials and placed onto a millipore filter in the filter apparatus. Each sample was then triple rinsed on the filter using de-ionized water to remove surface contamination and then dried on the filter in a 65 °C oven until reaching a constant weight. The filter and hair were then separated using acid-rinsed forceps. We weighed a hair sample of 10 ± 2 mg and placed it into a 20-ml straight walled vial. Two ml of 45-percent (w/v) sodium hydroxide and 1 ml of 1-percent (w/v)

L-cysteine was added and the mixture heated to near boiling with continuous gentle swirling. The solution was cooled and the volume adjusted to 10 ml with 1-percent (w/v) sodium chloride and then analyzed.

For soil analysis we removed samples from the sampling bag, mixed and placed them in beakers to air dry. Upon reaching constant air dry weight, we mixed the sample again. Samples of 0.2-gm were placed into a digestion bottle with 5.0 ml Aqua regia and heated for two minutes in a 95 °C water bath. After cooling, 50 ml of de-ionized water and 15 ml of potassium permanganate solution were added and the sample mixed and placed into a 95 °C water bath for 30 min. After cooling 6.0 ml of sodium chloride and 55 ml of de-ionized water were added before filtering and measuring the final sample volume for analysis.

The prepared hair and soil samples were analyzed for total mercury according to the U.S. Environmental Protection Agency (1991) method 245.5 and the equipment manufacturer's standard operating procedure for Cold Vapor Atomic Absorption Spectroscopy (CVAAS). For quality control we ran standard concentrations before and after each batch of 20 samples. Each batch included a blank and at least one replicated sample. The average difference between replicated samples was 8 percent for the soils and 19 percent for the hair samples.

RESULTS AND DISCUSSION

Mercury concentrations measured in hair and soils appear in Table 1. Compared to recent USGS data reported by Smith et al. (2005), the two sites impacted by mining (Silver and Trinity Creek) had highly elevated soil mercury concentrations; repository cover soils had slightly elevated concentrations; and the ranch site had similar concentrations. To compare our data to others, we used a total soil mercury content of 0.1 µg/g as a high concentration for background levels. Using 0.1 µg/g as background, we estimated ratios of site mercury concentrations to background as follows: 225:1 for Silver Creek; 12:1 for Trinity Creek; 1:1 for Comet Repository, and 0.4:1 for the Cascade ranch site. We considered a background ratio of > 10 to be contaminated.

Deer mice living in areas with contaminated soils had higher concentrations of mercury in their hair than mice from the other sites (Table1 and Fig. 1). The range of concentrations for mouse hair at the contaminated sites (1.42-15.25 µg/g)

Table 1. Mercury concentrations in soil and deer mouse hair from four Montana sites in June, 2003.

		Hg (µg /g)		
Location	**Number of Samples**	**Mean Deviation**	**Standard**	**Range**
Silver Creek				
Hair	15	4.47	2.371.42-11.17	
Soil	12	22.36	28.56	0.37-79.95
Trinity Creek				
Hair	7 5.15	4.82	1.26-15.25	
Soil	15	1.16	1.550.07-5.81	
Comet				
Hair	16	0.82	0.300.30-1.47	
Soil	10	0.10	0.090.01-0.23	
Cascade Ranch				
Hair	23	0.81	0.420.12-2.40	
Soil	10	0.02	0.005	0.018-0.03

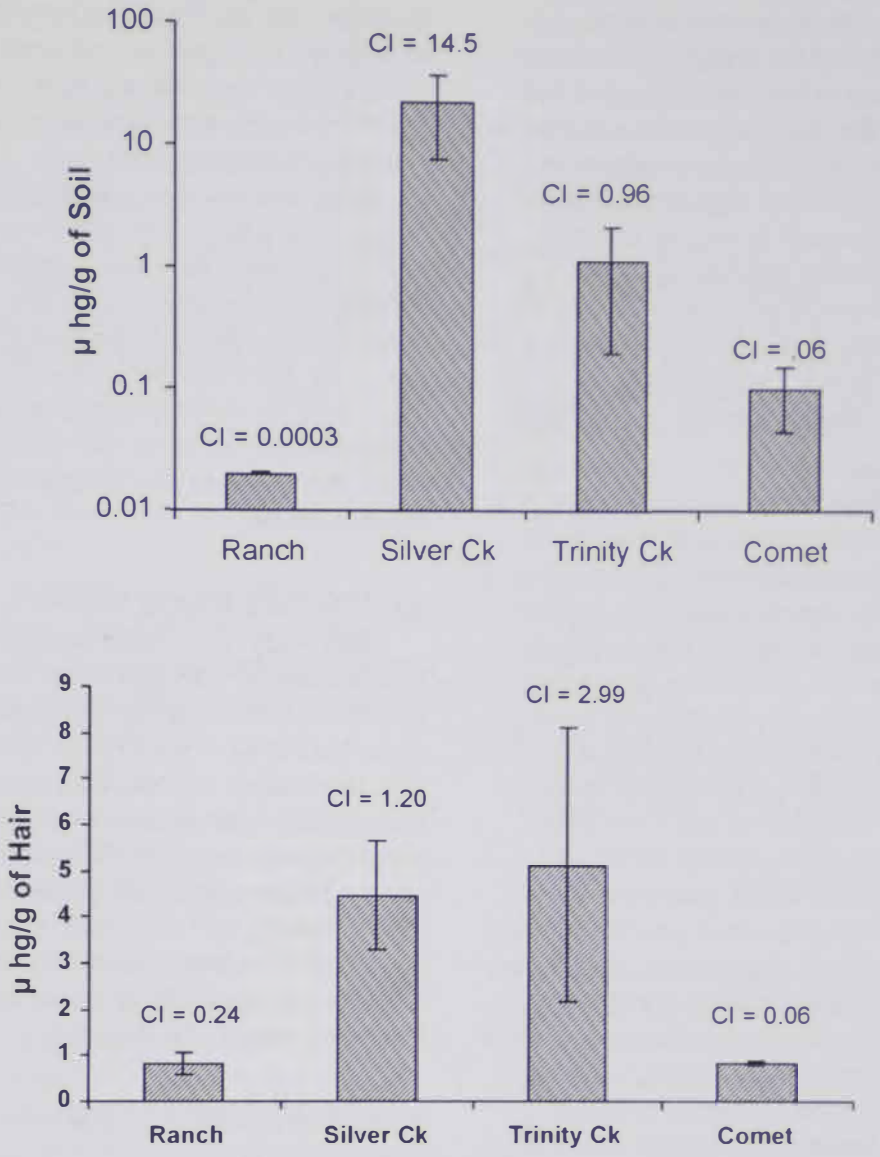

Figure 1. Average and 95-percent confidence intervals for mercury concentrations in soil and deer mouse hair from four Montana sites in June 2003.

overlapped each other as did those from the other sites (0.12-2.40 µg/g). However, only one of 39 samples from the uncontaminated sites overlapped the range of concentrations for the 23 samples from the contaminated sites. Our results show that mice from the two contaminated sites had hair mercury levels five to six times higher than mice from the uncontaminated sites, i.e., Comet Repository and the Cascade Ranch.

A comparison with deer mouse hair levels reported by Burton et al. (1977) shows that average levels at the Comet Repository and the Cascade Ranch about doubled the average levels Burton et al. (1977) reported for the rural Vernal site and one-half the levels reported from the Magna site. Average levels measured from our contaminated sites were approximately one-half those reported for the island sites but 14-16 times those found at the rural Vernal, Utah, site. Data from our study and Burton et al. (1977) show that mouse hair does indicate mouse exposure to environmental mercury.

We observed large differences in soil mercury concentrations among all sites (Fig. 1). Comparatively, we detected only slight

differences in hair concentrations between the two sites associated with mining activities that had the highest soil mercury concentrations or between the Comet and Ranch sites that had the lowest soil mercury concentrations (Fig. 1). All comparisons between sites that had high levels of soil mercury (Silver and Trinity) to sites with low levels (Comet and Ranch) showed large differences in hair concentrations of mercury. These results indicated that deer mice living on soils contaminated with mercury accumulate mercury in their hair.

CONCLUSIONS

An objective of this study was to determine if mice represent a pathway for environmental mercury transport. Our data show that mice in mercury contaminated environments did accumulate mercury in their hair and hence were an actual route for mercury transport and dissemination within an ecosystem. Because the levels of mercury in the leaves and roots of the vegetative species studied at the Silver Creek and Trinity Creek sites generally did not have elevated levels of mercury (Waring and Waring 2006), the source of the mercury in mouse hair did not likely result from consumption of vegetation. One hypothetical source of mercury in hair could result from surface deposition on hair followed by grooming. Another hypothetical source of mercury accumulation on hair could result from mice breathing/ingesting contaminated soil particles incidental to normal activity.

Although the hypothesized routes of exposure are interesting and worthy of future study, a more important aspect of our results lies in the fact that deer mice from contaminated environments accumulated more mercury in their hair than mice from uncontaminated sites. Thus, deer mice can be used as a long term bioindicator of the effectiveness of engineering treatments like repositories that are designed to isolate mercury. For example, from this study one might conclude that the Comet Repository prevented mercury in the repository tailings from contaminating mice in the ecosystem.

Further, since deer mice are relatively easy to capture and are found in a broad array of habitats, they could be monitored at a relatively low cost and long term biological monitor for sites constructed to isolate mercury containing wastes.

Deer mice and levels of mercury in their hair may be used to indicate levels of mercury where they live. Furthermore, depending on abundance, deer mice could be a significant factor in mobilizing mercury from soils into food chains. Routine monitoring for mercury in deer mouse hair could provide a valuable tool to assess future changes in environmental mercury concentrations.

ACKNOWLEDGEMENTS

This study was funded by the U.S. Environmental Protection Agency through its Office of Research and Development under IAG DW89938870-01-0 through the U.S. Department of Energy Environmental Management Consolidated Business Center under Contract DE-AC09-96EW96405 and implemented by MSE Technology Applications, Inc.

Former students Trisha Smith and Varadharajan Kailasam provided field and laboratory support for this study.

LITERATURE CITED

Burton G. V., R. J. Alley, G. L. Rasmussen, P.Orton, V. Cox , P. Jones, and D. Graff. 1977. Mercury and behavior in wild mouse populations. Environmental Research 14:30-34.

Douglass, R. J. 1984. The use of rodents in monitoring ecological impacts of oil shale development in the Piceance Basin, Colorado. *In* Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium. Thorne Ecological Institute Technical Publication 14. 250 pp.

Douglass, R. J. 1989. Assessment of the use of selected rodents in ecological monitoring. Environmental Management 13 355-363.

Fortin, C., G. Beauchamp, M. Dansereau, N. Lariviere, and D. Belanger. 2001. Spatial variation in mercury concentrations in wild mink and river otter carcasses from the James Bay Territory, Quebec, Canada. Arch. Environmental Contamination Toxicology 40:121-127.

Kosatsky, T., R. Przybysz and B. Armstrong. 2000. Mercury exposure in Montrealers who eat St. Lawrence River sportfish. Environmental Research 84:36-43.

Matsubara, J. and K. Machida. 1985. Significance of elemental analysis of hair as a means of detecting environmental pollution. Environmental Research 38:225-238.

Peterson, H. and M. Madden. 2006. Development of a new biomonitoring technique using domestic pets as sentinel species. Intermountain Journal of Sciences 12:27-43.

Phelps, D., and P.R. Buseck. 1980. Distribution of soil mercury and the development of soil mercury anomalies in the Yellowstone geothermal area, Wyoming. Economic Geology and the Bulletin of the Society of Economic Geologists.75:730-741.

Reynolds, K. D., M.S. Schwarz, C. A. McFarland, T. McBride, B. Adair, R. E. Strauss, G. P. Cobb, M. J. Hooper, and S. T. McMurry. 2006. Northern pocket gophers (*Thonomys talpoides*) as biomonitors of environmental metal contamination. Environmental Toxicology and Chemistry 25:458-469.

Skalski, J. 1984. Towards the use of faunal populations as cost-effective biomonitors. *In* Issues and technology in the management of impacted western wildlife. Proceedings of a national symposium. Thorne Ecological Institute Technical Publication 14. 250 pp.

Smith, D. B., W. F Cannon,. L. G. Woodruff, R.G. Garrett, R. Klassen, J. E. Kilburn, J. D. Horton, H. D.King, M .B. Goldhaber, and J. M. Morrison. 2005. Major-and trace-element concentrations in soils from two continental-scale transects of the United States and Canada. U.S. Geological Survey Open-File Report 2005-1253, 22pp.

U.S. Environmental Protection Agency. 1991. Methods for the Determination of Metals in Environmental Samples. EPA-600/4-91-010.

U.S. Environmental Protection Agency. 1997. Mercury Study Report to Congress. EPA- 452/R-97-0003.

U.S. Geological Survey. 1970. Mercury in the environment. USGS Professional Paper 713.

Waring, T. and K. Waring. 2006 Mercury Levels in Vegetation Growing on Contaminated Soils in Southwestern Montana. Intermountain Journal of Sciences 12:18-26.

Warren, H. V., R. E. Delavault, and J. Barakso. 1966. Some observations on the geochemistry or mercury as applied to prospecting. Economic Geology 61:1010-1028.

Received 27 March 2007
Accepted 15 February 2008

Risk Assessment of Lead Poisoning in Raptors Caused by Recreational Shooting of Prairie Dogs

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Abstract

Raptors that scavenge animals containing lead (Pb) bullet fragments are subject to Pb poisoning. We analyzed nestlings tissue for signs of PB poisoning in resident ferruginous hawk (*Buteo regalis*) and golden eagle (*Aquila chrysaetos*) populations near eight black-tailed prairie dog (*Cynomys ludovicianus*) colonies in Thunder Basin National Grassland (TBNG), Wyoming, to determine if recreational prairie dog shooting resulted in lead poisoning in these two raptor species. For a control, we collected tissue samples from ferruginous hawks at a reference site near Rawlins, Wyoming, where shooting did not occur. Analytical tests included Pb concentration, aminolevulinic acid dehydratase activity, hemoglobin levels, protoporphyrin levels, and packed cell volume in blood samples, and Pb content in feathers. We also recovered prairie dog carcasses to determine the amount and composition of bullet fragments. We did not detect Pb poisoning in nestling raptors at any of our sites. We did, however, detect bullet fragments in 40 percent (4/10) of prairie dog carcasses with a mean ± SD weight of 92.5 ± 60.7 mg/carcass (n = 4, Range = 10-146 mg/carcass). Our results suggested that analysis of feathers for clinical signs of Pb poisoning might be an unreliable technique. Even though we did not detect Pb poisoning, presence of Pb bullet fragments in prairie dog carcasses indicated that recreational shooting could cause Pb poisoning if raptors scavenge on those carcasses.

Key words: blood, ferruginous hawk, golden eagle, lead, prairie dog, shooting, toxicity

Introduction

Effects of lead (Pb) poisoning on waterfowl (Bellrose 1959, Forbes and Sanderson 1978) are well known. Raptors are also susceptible to Pb toxicity (Pattee and Hennes 1983, Harmata and Restani 1995, Wayland and Bollinger 1999, Miller et al. 2000). Although ferruginous hawks (*Buteo regalis*) and golden eagles (*Aquila chrysaetos*) generally prey on live animals, they also scavenge (Craig et al. 1990, Bechard and Schmutz 1995). Scavenging raptors may be especially vulnerable because they are more likely to encounter carcasses containing Pb bullet fragments (Pattee et al. 1990). Pauli and Buskirk (2007) documented that shot prairie dogs contain lead fragments and they may provide an important portal for lead entering wildlife food chains.

Thunder Basin National Grassland (TBNG) is the population center of black-tailed prairie dogs (*Cynomys ludovicianus*) in Wyoming. Golden eagles, ferruginous hawks, and other raptors that prey on prairie dogs also nest there. Annual use of TBNG by prairie dog shooters can be as high as

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8500 hunter-use days (TBNG, unpublished report). Prairie dog shooting has mostly been unregulated with the exception of the 2001 shooting closure of 29,340 ha (13%) of TBNG for the reintroduction of black-footed ferrets (*Mustela nigripes*). Prairie dog shooters do not collect carcasses, and golden eagles and ferruginous hawks are known to scavenge on these carcasses. The results of ingesting food items containing Pb are more severe to nestlings than adults of altricial birds such as golden eagles and ferruginous hawks (Hoffman et al. 1985). Forty percent of nestling American kestrels (*Falco sparverius*) that received a daily dose of 625 mg of metallic Pb in corn oil/kg of body weight died after 6 days (Hoffman et al. 1985).

During the nesting season of 2002, our goal was to determine if ferruginous hawk and golden eagle nestlings were exposed to harmful doses of Pb if they scavenged shot prairie dogs. Our first specific objective was to analyze blood and feather samples of ferruginous hawk and golden eagle nestlings for sub-clinical signs (0.2 to 1.5 µg Pb/g wet weight) of Pb poisoning. Sub-clinical levels are indicative of potential physiological injury from which the bird would probably recover if Pb exposure were terminated (Franson 1996). Our second objective was to assay the recovered bullet fragments to determine the amount of Pb/carcass.

Study Areas

We conducted our investigation at TBNG from April through July 2002. TBNG (43°30'00N, 105°15'00W) is part of Medicine Bow National Forest and is located in northeast Wyoming within Campbell, Weston, Converse, and Niobrara counties (Fig. 1). It covers > 231,000 ha of national forest lands that are interspersed with private, state and USDI Bureau of Land Management (BLM) lands. Fairly level plains, rolling hills, and steep escarpments characterize the topography of the area. Precipitation is < 30 cm/yr and elevation ranges from 1370 to 1600 m. Sagebrush (*Artemisia spp.*) communities composed of Wyoming big sagebrush (*A. tridentata wyomingensis*), needle-and-thread grass (*Stipa comata*), blue grama (*Bouteloua gracilis*) and western wheatgrass (*Agropyron smithii*) are the dominant vegetation type, and there are also ponderosa pine (*Pinus ponderosa*) forests and cottonwood (*Populus spp.*) corridors.

Our reference (control) site was located in south-central Wyoming (41°45'00N, 107°30'00W) near Rawlins. The area is characterized as a high, cool desert with < 30 cm of precipitation/year. Sagebrush communities are the most common vegetation type. Other assorted vegetation types are interspersed throughout the landscape including sagebrush/mountain shrub, saltbush steppe, greasewood lowlands and badlands. Ferruginous hawk and golden eagle nests were found at elevations between 1829 and 2134 m. Most nests were located on trees, platforms, and bluffs on private land where prairie dog shooting did not occur.

Methods

At TBNG, we located active ferruginous hawk and golden eagle nests by searching historical nest sites identified in USDA Forest Service (USFS), BLM, and Thunder Bird Wildlife Consulting (Wright, WY) records, and on-site searches. We monitored active nests within 5 km of prairie dog colonies where recreational shooting occurred in an attempt to focus on birds that may scavenge on shot prairie dogs. Breeding season home ranges of golden eagles in northern Wyoming were 26.1 to 54.0 km^2 for five pairs (Kochert et al. 2002). Home ranges of breeding male ferruginous hawks in Idaho were 7.6 km^2 (4.8–14.1, n = 7) (McAnnis 1990). Even though home ranges of adults nesting within 5 km of a prairie dog colony might not include the associated colony, we used this threshold to increase our sample size due to the low densities at which these raptors nest in TBNG. We collected blood samples only from nestlings to determine local bioaccumulation of Pb. Capture and handling protocols were reviewed and approved under the University of Wyoming Animal Care and Use Committee form number A-3216-01.

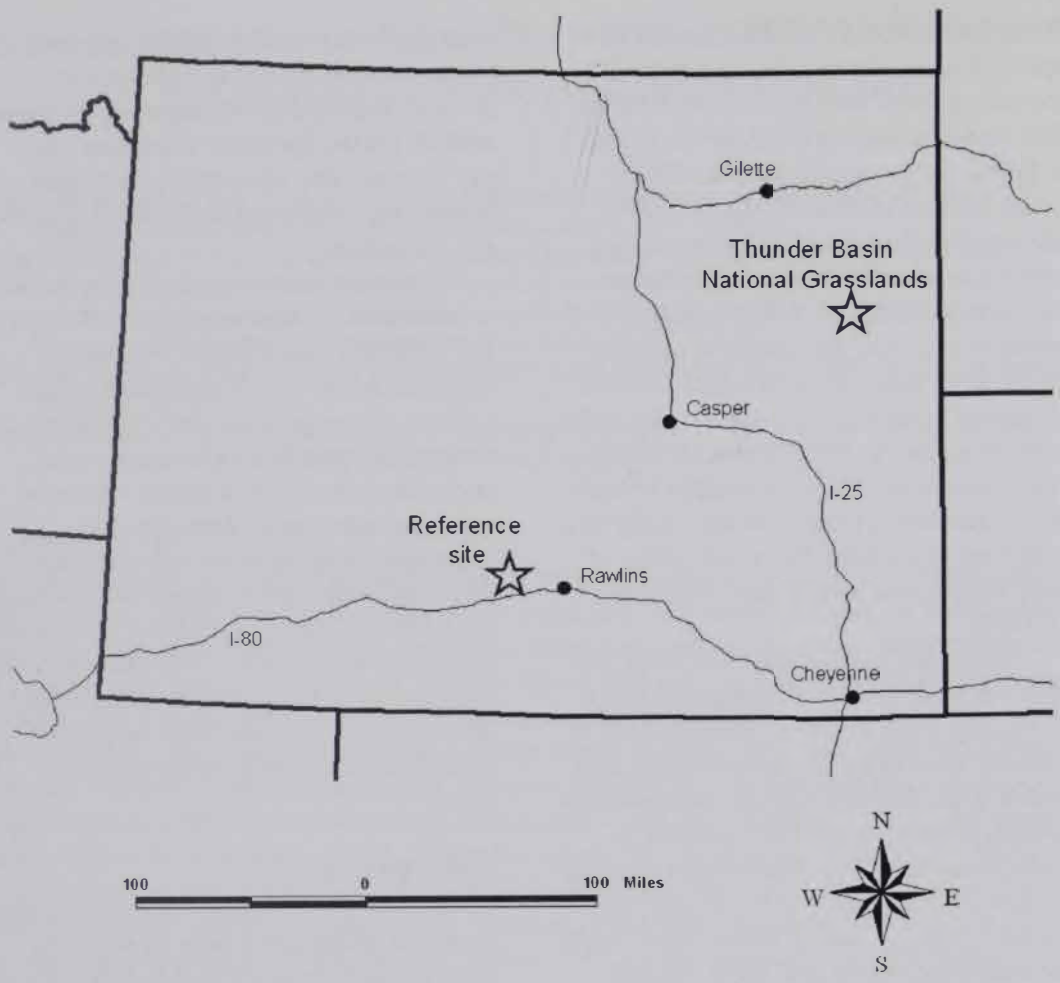

Figure 1. Study sites in Wyoming.

We collected 2.0 ml of blood from the brachial vein of ferruginous hawk and golden eagle nestlings using a syringe and performed five hematological analyses on the samples: 1) Pb concentration, 2) aminolevulinic acid dehydratase (ALAD) activity, 3) hemoglobin level, 4) protoporphyrin level and 5) packed cell volume (PCV). We divided the 2.0 ml of blood into four vials, each containing a 0.5 ml aliquot of blood for the first four analyses.

Blood Pb analyses were performed at the University of Wyoming's Red Buttes Environmental Biology Laboratory (RBEBL; Laramie, WY) on a Varian SpectrAA600 graphite furnace atomic absorption spectrophotometer equipped with Zeeman background correction (Fernandez and Hilligoss 1982). When Pb concentrations were below the detection limit, we used the mean of the detection limit and zero as an individual's Pb concentration based on the assumption that the Pb concentration fell between zero and the detection limit. We classified blood Pb concentrations in Falconiformes according to Franson (1996) and we also compared ferruginous hawk blood Pb levels at TBNG to the reference site using a Mann Whitney Test.

ALAD is an essential enzyme for heme synthesis, and its inhibition is a standard bioassay to detect Pb exposure in birds (Henny et al. 2000). ALAD activity was measured colorimetrically by the National Wildlife Health Center (Madison, WI) with a Beckman DU-65 spectrophotometer

(Beckman Instruments, Fullerton, CA), based on methods described by Burch and Siegel (1971). We determined ALAD activity with duplicate 0.1-ml aliquots of blood; we report the mean of the duplicates. One unit of enzyme activity is defined as an increase in absorbance at 555 nm of 0.100, with a 1.0-cm light path/ml of erythrocytes/hour at 38 °C.

Over-exposure to Pb also causes reduced total-blood hemoglobin concentration, elevated levels of protoporphyrin and decreased PCV (Hoffman et al. 1995). Antech Diagnostic (Irvine, CA) conducted hemoglobin analyses by the cyanmethomoglobin method and spectrophotometric measurement (Sari et al. 2001). We measured protoporphyrin levels (µg/dl of blood) with a hematofluorometer at 2, 24, and 48 hrs after blood collection (Franson et al. 1996). We used a heparinized capillary tube to collect blood from the puncture site for PCV analysis and spun the capillary tubes in a micro-centrifuge for 3 min. PCV was the percentage of red blood cells in whole blood determined by centrifuging whole blood. We evaluated the influence of Pb exposure on ALAD, hemoglobin levels, protoporphyrin levels and PCV by comparing the 95-percent confidence intervals for TBNG and the reference site.

We also evaluated the use of feathers as a less invasive sample for determining Pb poisoning. We pulled several pin or down, breast feathers from nestlings and stored them in plastic sample bags. Down feathers were only collected from nestlings that had not developed pin feathers at the time of sampling. Feathers were washed vigorously in 50-percent aqueous acetone followed by three rinses with deionized water to remove loosely adherent external contamination. Feathers were then air dried overnight at 60 °C and weighed to the nearest 0.1 mg. Weighed samples were digested at 180 °C for 10 min with a combination of 0.5 ml each H_2O_2 and HNO_3 in a microwave digestion system (MDS 2000, CEM Corp, Mathews, NC), cooled and diluted to 5 ml with deionized water. The diluted samples were analyzed together with appropriate standards, reference samples and Pb-spiked duplicates by ICP-MS at the WSVL. We used the mean of the detection limit and zero as an individuals Pb concentration when Pb concentrations were below the detection limit. Due to high detection limits of down feathers, we only used pin feathers in the linear regression analysis of Pb content in the blood and compared to feathers.

When we encountered shooters at prairie dog colonies, we collected and froze prairie dog carcasses within a few hours of shooting and had them radiographed at a veterinary clinic in Laramie, Wyoming. Guided by the radiograph, we dissected the carcass and searched for metal fragments. Metal fragments were weighed, digested in HNO_3 and H_2O_2, and analyzed on an Elan 6100 Inductively Coupled Plasma-Mass Spectrometry (ICP-MS; Perkin Elmer, Norwalk, CN). ICP-MS analyses were performed at the Wyoming State Veterinary Lab (WSVL) in Laramie according to their Standard Operating Procedure (WSVL 2001).

Results

We collected blood and feather (15:pin; 8:down) samples from 23 ferruginous hawk nestlings (26.5 ± 3.2 days old) at nine nests in TBNG. We also collected blood and six feather (5:pin; 1:down) samples from seven golden eagle nestlings in TBNG. At the reference site, we sampled 23 ferruginous hawk nestlings (39.2 ± 2.8 days old) from nine nests and obtained blood and feather (pin feathers only) samples from each hawk. Blood Pb samples from each site were below sub-clinical levels of 0.2 to 1.5 µg Pb/g wet weight (Table 1) and 88.7 percent of blood Pb samples (n = 53) were below detection limits. Blood Pb levels were higher for ferruginous hawks at the reference site than at TBNG (Mann Whitney, W = 323.0; $\alpha <$ 0.001). PCV was higher at the reference site (35.17– 37.25) than at TBNG (29.13–31.75). ALAD activity, hemoglobin levels, and protoporphyrin levels in ferruginous hawk and golden eagle nestlings at TBNG also suggested against Pb poisoning (Table 2).

Table 1. Blood Pb concentrations of ferruginous hawk (FEHA) and golden eagle (GOEA) nestlings sampled during June–July 2002 at Thunder Basin National Grasslands (TBNG) and the reference site (REF) near Rawlins, Wyoming.

Species	Site	*n*	Minimum (µg Pb/g)	Maximum (µg Pb/g)	Mean (µg Pb/g)	Detection Limit (Mean ± SD; µg Pb/g)
FEHA	TBNG	23	0.020	0.061	0.025	0.044 ± 0.004
FEHA	REF	23	0.023	0.167	0.034	0.049 ± 0.002
GOEA	TBNG	7	0.021	0.074	0.032	0.044 ± 0.006

Table 2. Blood constituents used to compare lead toxicity of ferruginous hawk (FEHA) and golden eagle (GOEA) nestlings sampled at Thunder Basin National Grasslands (TBNG) and a reference site (REF) near Rawlins, Wyoming, 2002.

Parameter	Species	Site	*n*	Mean ± SD	95% Confidence Interval
ALAD	FEHA	TBNG	23	353 ± 66	326 – 380
(Burch & Siegel Units)	FEHA	REF	22	289 ± 27	277 – 300
	GOEA	TBNG	5	466.4 ± 31.7	404.3 – 528.5
Protoporphyrin[1]	FEHA	TBNG	23	15.7 ± 7.1	12.8 – 18.5
(µg/dl)	FEHA	REF	23	10.5 ± 2.8	6.2 – 14.8
	GOEA	TBNG	7	35.9 ± 22.0	-7.9 – 72.0
Hemoglobin	FEHA	TBNG	23	10.3 ± 2.3	9.4 – 11.3
(g/dl)	FEHA	REF	13	11.6 ± 1.9	10.4 – 12.5
	GOEA	TBNG	6	9.7 ± 1.0	7.87-11.59
PCV	FEHA	TBNG	23	30.4 ± 3.2	29.1 – 31.8
(% RBC in whole blood[2])	FEHA	REF	23	36.2 ± 2.6	35.2 – 37.3
	GOEA	TBNG	6	30.3 ± 6.0	25.46 – 35.1

[1] Levels reported were measured at 48 hours after blood collection

[2] Red blood cells

Table 3. Feather Pb concentrations in ferruginous hawks (FEHA) and golden eagles (GOEA) at Thunder Basin National Grasslands (TBNG) and a reference site (REF) near Rawlins, Wyoming, 2002.

Species	Site	Feather Type	*n*	Minimum (µg Pb/g)	Maximum (µg Pb/g)	Mean (µg Pb/g)	Detection Limit (Mean ± SD; µg Pb/g)
FEHA	TBNG	Pin	15	0.08	24.72	0.20	0.314 ± 0.139
		Down	8	0.183	1.306	0.498	0.921 ± 0.367
FEHA	REF	Pin	23	0.48	2.616	0.122	0.140 ± 0.046
GOEA	TBNG	Pin	6	0.101	1.935	0.443	0.094 ± 0.063
		Down	1	--	1.070	--	0.314

Feather Pb concentrations are presented in Table 3. We found no relationship between feather Pb and blood Pb concentrations (F = 1.31 – 9.1 x blood Pb concentration; $r^2 = 0.4$, $P = 0.16$).

We collected 10 carcasses of shot prairie dogs and found bullet fragments in four carcasses (Table 4). The mean total weight of the bullet fragments recovered/carcass was 92.5 ± 60.7 mg (Mean ± SD; $n = 4$). The mean weight of individual fragments recovered was 24.7 mg. Three carcasses contained greater than trace amounts of Pb, which averaged 57.3 ± 57.9 mg. Copper (Cu) was the primary metal (≥ 78% of total metals) in three samples and was accompanied by traces of zinc (Zn). Fragments in the fourth carcass were almost entirely Cu with trace amounts of Pb and Zn.

Discussion

Blood Pb concentrations in all ferruginous hawks and golden eagles sampled were below sub-clinical levels. However, amounts detected at both sites indicated that Pb occurred at low levels. Blood Pb levels were higher for ferruginous hawks at the Rawlins reference site but were likely due to the older age of Rawlins nestlings at time of sampling. Average age of nestlings sampled in TBNG and Rawlins were 26.5 and 39.2 days, respectively, providing Rawlins nestlings with a longer exposure to environmental Pb sources.

Comparisons of ALAD activity, protoporphyrin levels, and hemoglobin levels of ferruginous hawks between sites also indicated Pb poisoning was not occurring in the raptors we sampled at TBNG. PCV was lower at TBNG though but this difference was also likely due to the younger age of TBNG nestlings when sampled. PCV increases in young animals with age to fulfill increasing metabolic demands for oxygen associated with increasing body size (Rawson et al. 1992).

Several factors may explain why Pb levels in raptors were low. First, a sylvatic plague (*Yersinia pestis*) epizootic drastically reduced prairie dog numbers at many colonies in TBNG during 2001-2002. Second, 13 percent of TBNG was closed to prairie dog shooting in 2001 in an effort to reintroduce black-footed ferrets. New shooting regulations and a dwindling prairie dog population reduced the number of shooters that visited TBNG during the course of our study relative to previous years. Finally, long-term surveys in this area indicated an abundance of lagomorphs during our study, thus reducing the likelihood of raptors scavenging shot prairie dogs.

We found that feather Pb concentrations were much higher than blood Pb concentrations. Burger and Gochfeld (2000) also reported that the type of tissue analyzed is the strongest contributor responsible for variation in concentrations of metals with Pb concentrations highest in feathers. However, we were unable to use this as an additional measure of Pb toxicity because there was no relationship between concentrations of feather Pb and blood Pb, and the literature

Table 4. Metal content of bullet fragments recovered from 10 prairie dog carcasses collected at Thunder Basin National Grasslands, 2002.

Sample	Rifle Caliber	Total Weight	Number of Fragments	Pb Content		Cu Content		Zn Content
				%	Mg	%	Mg	%
1	0.22-250	146 mg	4	191	28	761	113	< 1
2	0.22-250	10 mg	1	< 0.1	TS2	106	10	< 1
3	0.25-06	85 mg	6	23	20	79	67	< 1
4	0.243	129 mg	4	96	124	< 1	?	< 1

[1] Very high concentration of Pb and Cu required repeated dilution to estimate percentages of each metal; thus the percentages do not equal 100 percent.

[2] Too small to estimate

lacks reference values for Falconiformes feather Pb concentrations as indicators of Pb poisoning.

We found bullet fragments in 40 percent of prairie dog carcasses examined; bullet types were unclassified. Cu was the dominant metal present in recovery and analysis of bullet fragments from prairie dog carcasses. However, we did not analyze Cu concentrations in blood, and we found no information in our literature review on Cu toxicity in avian wildlife (Eisler 1998). Further research is needed before the implications of Cu consumption by raptors can be assessed.

Pauli and Buskirk (2007) reported that 87 percent of prairie dogs shot with expanding bullets contained bullet fragments, whereas only 7 percent of carcasses shot with non-expanding bullets did. Also, carcasses shot with expanding bullets contained a mean of 228.4 mg of lead-containing bullet core, whereas carcasses shot with non-expanding bullets averaged only 19.8 mg of Pb. We detected fragments with an average weight of 24.7 mg and contained an average of 11.5 mg of Pb. As suggested by Pauli and Buskirk (2007), fragments < 25 mg are likely small enough to be ingested and absorbed by secondary consumers.

Even though we did not detect Pb poisoning at TBNG, our results confirmed that some carcasses of shot prairie dogs contain Pb fragments and scavenging could result in Pb poisoning. The occurrence of Pb poisoning in TBNG is likely related to prairie dog and raptor abundance, availability of alternate food sources and regulations on shooting.

Acknowledgements

The authors are thankful of the USDI Fish and Wildlife Service and Wyoming Game and Fish Department for funding this research, and to the late Stan Anderson for facilitating the project. Additionally, L. Apple, T. Byer, K. Clayton, C. J. Boese, C. Franson, K. Gordon, S. Hess, K. Keffer, S. Lantz, C. Lockman, J. S. Meyer, B. Oakleaf, M. Raisbeck, and R. Siemion made significant contributions. Finally, we thank G. Dusek, D. Goltz, H. Hansen, A. Harmata, W. Hubert, A. Kuenzi, D. Lapointe, M. Long, J. Meyer and three anonymous reviewers for their helpful suggestions in improving the manuscript.

Literature Cited

Bechard, M. J. and J. K. Schmutz. 1995. Ferruginous hawk (Buteo regalis). In A. Poole and F. Gill (eds.)The Birds of North America, No. 172, The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.

Bellrose, F. C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Natural History Bulletin 27:235-288.

Burch, H. B. and A. L. Siegel. 1971. Improved method for measurement of delta-aminolevulinic acid dehydratase activity of human erythrocytes. Clinical Chemistry 17:1038-1041.

Burger, J. and M. Gochfeld. 2000. Metals in Laysan albatrosses from Midway Atoll. Arch. Environmental Contamination and Toxicology 38:254-259.

Craig, T. H., J. W. Connelly, E. H. Craig, and T. L. Parker. 1990. Lead concentrations in golden and bald eagles. Wilson Bulletin 102:130-133.

Eisler, R. 1998. Copper hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR--1998-0002.

Fernandez, F. J. and D. Hilligoss. 1982. Improved graphite furnace method for determination of lead in blood using matrix modification and the L'vov platform. Journal of Analytical Atomic Spectroscopy 3:130-131.

Forbes, R.M. and G.C. Sanderson.1978. Lead toxicity in domestic animals and wildlife. Pp 225-277 in J.O Nriagu, editor, The biogeochemistry of lead in the environment. Part B: biological

effects. Elsevier/ North Holland Biomedical Press, Amsterdam, New York, and Oxford. 397 pp.

Franson, J. 1996. Interpretation of tissue lead residues in birds other than waterfowl. In W. N. Beyer, G. H. Heinz, and A. W. Redmon-Norwood, editors, Environmental Contaminants in Wildlife: interpreting tissue concentrations, Lewis Publishers, Boca Raton, FL. 265 pp.

Franson, J. C., W. L. Hohman, J. L. Moore, and M. R. Smith. 1996. Efficacy of protoporphyrin as a predictive marker for lead exposure in canvasback ducks: effect of sample storage time. Environmental Monitoring Assessment 43:181-188.

Harmata, A. R. and M. Restani. 1995. Environmental contaminants and cholinesterase in blood of vernal migrant bald and golden eagles in Montana. Intermountain Journal of Sciences 1:1-15.

Henny, C. J., L. J. Blus, D. J. Hoffman, L. Sileo, D. J. Audet, and M. R. Snyder. 2000. Field evaluation of lead effects on Canada geese and mallards in the Coeur d'Alene River Basin, Idaho. Archives of Environmental Contamination and Toxicology 39:97-112.

Hoffman, D. J., J. C. Franson, O. H. Pattee, C. M. Bunck, and H. C. Murray. 1985. Biochemical and hematological effects of lead ingestion in nestling American kestrels (Falco sparverius). Comparative Biochemistry and Physiology 80:431-439.

Hoffman, D. J., B. A. Rattner, G. A. Burton, Jr., and J. Cairns, Jr. 1995. Handbook of Ecotoxicology. Lewis Publishers. Ann Arbor, MI.

Kochert, M. N., K. Steenhof, C. L. McIntyre, and E. H. Craig. 2002. Golden Eagle (Aquila chrysaetos). In A. Poole and F. Gill, editors, The Birds of North America, No. 684 . The Birds of North America, Inc., Philadelphia, PA.

McAnnis, D. M. 1990. Home range, activity budgets, and habitat use of Ferruginous Hawks (Buteo regalis) breeding in southwest Idaho. Master's thesis, Boise State University, Boise, ID.

Miller, M. J. R., M. E. Wayland, E. H. Dzus, and G. R. Bortolotti. 2000. Availability and ingestion of lead shotshell pellets by migrant bald eagles in Saskatchewan. Journal of Raptor Research 34:167-174.

Pattee, O. H. and S. K. Hennes. 1983. Bald eagles and waterfowl: the lead shot connection. Transactions of the North American Wildlife and Natural Resources Conference 48:230-237.

Pattee, O. H., P. H. Bloom, J. M. Scott, and M. R. Smith. 1990. Lead hazards within the range of the California condor. The Condor 92:931-937.

Pauli, J. N. and S. W. Buskirk. 2007. Recreational shooting of prairie dogs: A portal for lead entering wildlife food chains. Journal of Wildlife Management 71:103-108.

Rawson, R. E., G. D. DelGiudice, H. E. Dziuk, and L. D. Mech. 1992. Energy metabolism and hematology of white-tailed deer fawns. Journal of Wildlife Diseases 28:91-94.

Sari, M., S. de Pee, E. Martini, S. Herman, Sugiatmi, W. M. Bloem, and R. Yip. 2001. Estimating the prevalence of anemia: a comparison of three methods. Bulletin of the World Health Organization 79:506-511.

Wayland, M. and T. Bollinger. 1999. Lead exposure and poisoning in bald eagles and golden eagles in the Canadian prairie provinces. Environmental Pollution 104:341-350.

Wyoming State Veterinary Lab. 3/21/01. Toxicology Section, Lead Standard Operating Procedure, Laramie.

Received 14 November 2003
Accepted 20 February 2008

ABSTRACTS

BIOLOGICAL SCIENCES – AQUATIC

ABSTRACTS OF THE 2007 ANNUAL MEETING OF THE THE AMERICAN FISHERIES SOCIETY 40TH ANNUAL MEETING

RETURN TO THE RIVER: REVISITING AND REINVIGORATING THE SOURCE OF OUR PASSION AND PROFESSIONALISM

FEBRUARY 13-16, 2007

MISSOULA, MONTANA

RELATING FISH ASSEMBLAGES TO ENVIRONMENTAL PATTERNS AT THREE MULTI-STATE SCALES

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Key challenges to studying and managing riverscapes include understanding how factors measured at various spatial-scales influence aquatic biota and developing accurate predictive models where study data are limited. Currently fish zones, physiographic regions, ecoregions, and river basins are commonly used for classifying fish faunas. All these classifications reduce the apparent variability occurring at a large scale, but also include considerable heterogeneity. We analyzed a 780-site data set obtained from the U.S. Environmental Protection Agency's EMAP western survey. First, we determined fish clusters at three spatial scales in the western U.S., i.e., all 12 conterminous states, all western mountains, Pacific Northwest mountains. We next determined that the predictor variables for those clusters changed with spatial scale. For example, longitude, dams and temperature were the best predictors for all sites, longitude, dams and catchment area were the top predictors for mountain sites, and latitude, turbidity, and canopy density ranked highest for Pacific Northwest mountains. The best three variable models included site, basin, and ecoregion predictor variables. However, basin, ecoregion, state, and abiotic site variables alone only accounted for half of the mean within-group similarity demonstrated by the fish clusters. We conclude that using large quantitative fish assemblage data sets linked with quantitative physical and chemical habitat data and landscape data to predict fish assemblage patterns is preferable to using preexisting landscape classifications.

An Outbreak Of Viral Hemorrhagic Septicemia IN The Great Lakes: Montana's Next Whirling Disease?

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Viral Hemorrhagic Septicemia (VHS) is an aquatic rhabdovirus that has the potential to cause significant mortality in fish. It is believed to have originated in Europe where it affects mostly freshwater fish in culture situations. It was first reported in the United States in 1988 and has since become enzootic in the Pacific Northwest in several marine species includ-ing pacific herring and several salmon species. In 2005 a variant of the virus was discovered in the Great Lakes Region and has been associated with significant mortality in a variety of freshwater fish species. Although the origin of this Great Lakes genotype of VHS is unclear, it has demonstrated the ability to cause severe mortality among a number of species unaf-fected by previously isolated strains of the virus, including most game fish found in Montana. Due to this unique characteristic, the outbreak in the Great Lakes generated an unprecedented regulatory response from a variety of state and federal agencies. There is already in place a national framework of regulations at various jurisdictional levels aimed at preventing the spread of destructive pathogens and organisms; however, it is not a perfect system. It is im-portant to remain active and informed at the local level so as to increase our protection even more. Though it has not been found in Montana, this pathogen has significant implications to fisheries managers in Montana. It is important to remain vigilant in our oversight of potential transmission vectors to ensure that this pathogen does not find its way into Montana waters.

Nuisance Alga Didymosphenia Geminata: A Threat To Our Fisheries

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Didymosphenia geminata, a type of freshwater diatom alga, has recently been docu-mented outside its historic northern circumboral range and has resulted in highly visible algal blooms. Additionally, in locations with previous record of *D. geminata* in North America, al-gal growth has increased in spatial coverage and temporal persistence. The changes in growth habit may negatively impact fisheries and macroinvertebrates. Nuisance benthic growth of *D. geminata* can extend for greater than 1 km, persist for several months of the year, and cover up to 100 percent of substrate with thicknesses > 20 cm. Nuisance growth, characterized by thick mats that cover the stream bed, consists primarily of mucopolysaccaride stalks secreted by single cells of *D. geminata*. The thick mats are resistant to degradation and may influence the ecological properties of the stream, e.g., species diversity, population sizes, nutrient pools, alter the invertebrate food base, and reduce appropriate habitat and spawning sites for fish. The observed nuisance and invasive behavior patterns of *D. geminata* have prompted studie to improve our understanding of and methods to control this species. Research that examines the impact of algal blooms on species composition and diversity is underway. Studies suggest that *D. geminata* may be transported to new locations by recreational activities and equip-ment. With such limited information available on the basic biology of this species and little understanding of its impacts on fisheries, the best current defen ce against this alga is to limit its spread to new locations with proper equipment cleaning technique. and effective outreach education.

Fish Assemblages In The Powder And Tongue Rivers In Relation To Coalbed Natural Gas Development

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The Powder River Basin in Wyoming and Montana is currently undergoing one of the world's largest coalbed natural gas (CBNG) developments. Potential exists for substantial effects on aquatic ecosystems because CBNG development involves production and disposal of large quantities of coalbed ground water that differs from surface waters. We used four different approaches to determine the effects of coalbed natural gas development on fish assemblages in streams of the Powder River Basin in 2005 and 2006. First, we compared fish assemblages in streams with CBNG development and streams without development. Second, we compared the longitudinal distribution patterns of fish assemblages at multiple points above and below CBNG development. Third, we compared fish assemblages present in 2006 to fish survey data from the mid 1990s in areas with and without CBNG development. Finally, we compared growth and survival of native fish in streams with and without CBNG development. Several fish metrics and an index of biotic integrity were used to compare fish assemblages in relation to the status of development within a drainage area. Streams in drainages with CB G development on average had lower species richness than those without development.

Spatiotemporal Variation In Prairie Stream Fish Assemblages

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Fisheries biologists must be certain that their samples represent true parameters to make sound management decisions. Thus, assessing the spatiotemporal variation of fish assemblages in Montana prairie streams will allow for a better understanding of these ecosystems and their management. We used stratified random sampling to select five tributaries of the Yellowstone River that represent a gradient of stream sizes. To assess spatial variation, fish were sampled at sites arrayed from the confluence to the headwaters of each stream during June and July 2005 and 2006. To assess temporal variation, downstream, middle, and headwater sites, i.e., drainage position, were sampled on each stream in spring 2005 and summer and fall 2005 and 2006. In general, species richness increased with increasing watershed size from 16 to 26 species. Species richness varied spatially and decreased from downstream to upstream sites. Species richness in the smallest stream varied spatially from 12 to 0 (CV = 86.73) species; likewise, species richness varied from 16 to 2 (CV = 41.63) in the largest stream. The downstream site of the largest stream exhibited the greatest temporal variation in species richness—from 16 to 9 species (CV = 1.03). Overall, species richness did not vary consistently among seasons. Canonical correspondence analysis showed that drainage position and proportion of fine substrate were significant in explaining the most variation in fish assemblage structure. Given logistic and monetary constraints, we suggest that biologists design their surveys to maximize spatial coverage to adequately characterize fish assemblages of prairie streams.

Assessment Of Post-Stocking Dispersal Of Age-1 Pallid Sturgeon: Implications For Acclimation

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A propagation program for pallid sturgeon (*Scaphirhynchus albus*) in the upper Missouri River was implemented by theUSDI Fish and Wildlife Service in 1997. However, evidence suggests that many hatchery-reared pallid sturgeon are experiencing significant downstream post-stocking dispersal, negatively affecting their recruitment. Therefore, the objective of this study was to evaluate the effects of acclimation to flow and site-specific water conditions on post-stocking dispersal of age-1 pallid sturgeon. Fish from three acclimation treatments were radio-tagged, released at two locations, and monitored using passive remote telemetry stations. Treatment 1 fish were acclimated to flow and site specific water conditions in tanks along the Marias River. Treatment 2 fish were acclimated to flow in tanks at the Bozeman Fish Technology Center (BFTC), and Treatment 3 fish were reared with no acclimation at the BFTC. In 2005 Treatment 2 experienced 100 percent mortality. Further, Treatment 1 fish drifted less, experienced lower mortality, and nearly twice as many fish remained in suitable pallid sturgeon habitat than Treatment 3 fish. In 2006, drift rates, mortality rates, and fish remaining in suitable habitat were similar among treatments. In both years, all pallid sturgeon drifted less in the lower reaches of the study area where more sand substrate is present. Fin curl was present in nearly all individuals in 2005, and 28 percent of individuals in 2006. These data suggest that acclimation can reduce post-stocking dispersal when fin curl is present.

Population Viability Of Arctic Grayling In The Gibbon River, Yellowstone National Park

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Fluvial Arctic grayling (*Thymallus arcticus*) are presently restricted to < 5 percent of their native range in the contiguous United States and are listed as Category 3 under the Endangered Species Act. Fluvial grayling are thought to be restricted to a segment of the Big Hole River, Montana, in which declining abundances have been observed since 1998. Although fluvial grayling of the Madison, lower Firehole, and lower Gibbon Rivers of Yellowstone National Park were thought to be extirpated by 1935, anglers report catching grayling throughout the Gibbon River annually. Our goal was to determine if a viable population of fluvial grayling persists in the Gibbon River, or if fish caught in the river are downstream emigrants from lacustrine populations in headwater lakes. In 2005 and 2006, sixteen and fourteen grayling respectively, were sampled from the Gibbon River by electrofishing and fly-fishing. In both years, fry-trapping yielded no grayling at sites on the Gibbon River below the farthest upstream barrier to headwater lakes (Little Gibbon Falls). Sixteen grayling were caught on

a weir established above Little Gibbon Falls in 2006. Genetic analyses will be performed in 2007 on grayling within and outside of the Gibbon River System. Few grayling adults and fry inhabit the Gibbon River, implying that a reproducing fluvial population may not exist. Our findings may affect the potential Endangered Species Act listing of fluvial grayling while providing valuable data for sound management within and outside of Yellowstone National Park.

Lake Trout Suppression In Lake Pend Oreille Idaho – Will It Work?

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The lake trout population in Lake Pend Oreille, Idaho has been increasing exponentially since about the mid 1990s threatening the collapse of the kokanee population and one of the best adfluvial bull trout populations remaining in the Pacific Northwest. Traditional sport angling has done little to curb lake trout population growth. Deep water trap nets were used to estimate lake trout population abundance and evaluate harvest efficiency. Lake trout abundance was estimated at 6400 fish > 52 cm in 2003 and 10,700 in 2005. The steep sides and extreme depth of Lake Pend Oreille limited harvest efficiency by trap netting to about 12 percent. Based on recaptures in gill nets, the estimated population was 35,800 fish with 15,600 > 52 cm. An aggressive angler incentive program using $110,000 of Avista mitigation funding was used to encourage harvest of rainbow and lake trout to reduce predation on kokanee. A $10/fish bounty was more effective at motivating anglers than rewards based on PIT tags ($100-$2000), lottery tickets, or monthly cash drawings for every fish entered. Anglers harvested 5800 rainbow trout and 10,800 lake trout between May and November. The combined exploitation from netting and angling resulted in a total annual exploitation rate on lake trout of 44 percent and total annual mortality rate of 60 percent. We conclude that lake trout suppression can only be achieved through a combination of netting and angling. Next, we will employ population models to estimate the number of years needed to collapse the lake trout population in Lake Pend Oreille.

Are Anglers Able To Reduce Lake Trout Abundance In Flathead Lake?

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Flathead Lake's native fish fauna have declined in large part from predation by introduced lake trout (*Salvelinus namaycush*). The state and tribal co-managers completed a plan in 2000 to reduce the lake trout population. The primary strategy to accomplish this goal is recreational angling. We improved access and increased bag limits, number of lines, and publicity, but have yet to substantially increase harvest > 40,000 fish. While catch rates are high and increasing, anglers resist keeping large numbers of fish. We addressed this behavior with fishing contests where participants receive lottery tickets for every fish they harvest. The contests are growing rapidly, accounting for > 11,000 fish in 2006. Many have equated the success of these contests with reduction of the lake trout population, but our data contra-

dict this conclusion. We estimated the harvest needed to reduce the population so we could better evaluate which tools were capable of achieving that harvest. We estimated that a total harvest of 60,000 lake trout would result in a mortality rate sufficient to cause the population to decline. With increased angler incentives this harvest may be achievable in two years However, the degree of compensation that the increased harvest will cause is unknown. We have measured reductions in growth rates and increases in age at maturity of lake trout that indicate a large compensatory reserve that must be overcome. While reaching the 60,000 target by angling appears imminent, it is presently speculative whether the additional compensatory recruitment can be removed by angling alone.

Lake Trout Suppression In Yellowstone Lake: The Reality Of This Battle For Cutthroat Trout Persistence

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Soon after the 1994 discovery of lake trout in Yellowstone Lake, Yellowstone National Park initiated a gillnetting program aimed at suppression of the population. In 2001 our efforts were enhanced by acquisition of a Great Lakes-style gillnetting boat and funding to support additional staff. From 2001 to 2006 we set 105,000 net nights of gillnet (100 m/night) and removed 170,000 lake trout. Despite this effort, lake trout remain abundant. A new spawning site was discovered in 2006, and increasing numbers of smaller, immature lake trout have been removed for the fifth year in a row. Suppression efforts are surely slowing the rate of population growth, but whether or not the program will be able to suppress the lake trout population to an equilibrium that allows cutthroat trout to co-exist is unknown. Recent results are encouraging, in that larger, older lake trout continue to be caught with low frequency, and the mean length of lake trout caught on spawning areas has declined each year (559 mm in 2001 as compared to 505 mm in 2006). Program effectiveness is now being evaluated through collaboration with scientists at Montana State University and USGS Cooperative Fisheries Research Units in Montana and Wyoming. Population models created during the next two years, based on information collected over the past decade, will help to guide our program. As lake trout will never be fully removed from Yellowstone Lake, the development of new, advanced techniques for improving efficiency of suppression efforts is needed for this program to continue long term.

Lake Trout IN The Lakes Of Glacier National Park, Montana

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Glacier National Park, Montana, contains a significant portion of natural lake habitat available to adfluvial populations of bull trout (*Salvelinus confluentus*) throughout the United States. Because of the complex landscape in Glacier National Park some bull trout populations are relatively isolated; however, other populations are less isolated and susceptible to

deleterious effects of invasion by nonnative species. Of particular concern is the invasion by nonnative lake trout (*Salvelinus namaycush*), which was introduced into the Flathead drainage in the early 1900s. Past research has shown that invasion by lake trout may result in significant declines in bull trout populations. However, little effort has been made to manage the invasion in lakes within Glacier National Park. Using historical and contemporary data we examined the effect of lake trout invasion on bull trout populations in the four largest lakes in Glacier National Park west of the Continental Divide; Bowman Lake, Kintla Lake, Lake McDonald, and Logging Lake. Dramatic declines in bull trout numbers were observed over the last 36 years, these declines were associated with an increase in the numbers of lake trout. In 2005, relative abundance (mean catch/unit effort) of lake trout was 2.85 to 4.06 times higher than that of bull trout among lakes. These data suggested that further invasion by lake trout in this system may have a negative effect on native bull trout populations under a management strategy of "no action."

Lake Trout Population Control In Lake Pend Oreille, Idaho: Reversing Lessons From The Great Lakes

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The lake trout (*Salvelinus namaycush*) is widely distributed throughout the northern half of North America, but is generally thought to be susceptible to recruitment over-fishing because of its long-lived, late-maturing life history. For example, in the Laurentian Great Lakes, the World's largest lake trout populations were nearly extirpated by excessive fishery exploitation and predation by non-native sea lampreys. Experience in the Great Lakes shows that lake trout stocks have been exceedingly slow to recover, largely because fishery exploitation has been excessive. Lake trout stocks have recovered only in Lake Superior and isolated areas of Lake Huron, whereas populations are sustained by hatchery production elsewhere in the basin. Therefore, lake trout populations in western lakes, where the species was introduced in the early 1900s, but is now negatively impacting native species such as bull trout (Salvelinus confluentus), should be relatively easy to control through intentional programs of excessive fishery exploitation. Why then has lake trout population control been elusive in most western lakes? We suspect that fishery exploitation has not been high enough to drive lake trout populations into collapse in most western lakes. In contrast, population modeling suggests that exploitation on the lake trout population in Lake Pend Oreille, Idaho, during 2005–2006 will cause the population to collapse, if maintained for at least several years. If successful, the lake trout population control program on Lake Pend Oreille will provide fishery managers throughout the West with a formula for similar programs elsewhere.

Simple Population Models: What Can They Tell Us About Lake Trout Suppression?

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Simple population model projections and elasticity analyses have been used in evaluating and prioritizing techniques for population conservation. These types of analyses have been particularly effective in comparing the relative impact of different conservation efforts. These same techniques can help us compare potential lake trout population suppression efforts. We built an age-based matrix model for a lake trout population and parameterized it with both unpublished data of lake trout in Flathead Lake and other published demographic studies of lake trout. We then examined multiple model simulations to begin to evaluate potential suppression scenarios for a newly established lake trout population. Overall lake trout adult survival had high elasticity values, implying that a proportional change in demographic rates of this life stage would produce a relatively large impact on population growth rates. Eradication often requires decreased survival of multiple life stages. Techniques that reduce egg survival in addition to decreased adult survival can influence population numbers substantially. Scenarios with adult and egg survival reduced (75 and 50%, respectively), population sizes decreased by one-half after 15 years over reducing adult survival alone. This benefit of increased egg mortality is dependent upon the role of density-dependence in early life history stages. Finally, we examined scenarios associated with delaying suppression a decade as the population continues to increase. As expected, to either maintain the lake trout population at a set reduced level or eradicate the population, delaying suppression efforts results in either more or a longer effort required to achieve a similar end point.

Analyzing Tradeoffs Between The Threat Of Invasion By Nonnative Trout And Effects Of Intentional Isolation For Native Westslope Cutthroat Trout Using A Bayesian Belief Network

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Conservation of inland cutthroat trout can involve either the placement or removal of migration barriers to address threats from invading species and habitat fragmentation, respectively. Such efforts may proceed without a formal mechanism for considering potential tradeoffs from addressing these competing threats. A consistent decision process would include an analysis of when and where intentional isolation or removal of barriers is most appropriate, and we explored the application of a Bayesian belief network (BBN) as a tool for such analyses. We focused on westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) and nonnative brook trout (Salvelinus fontinalis), and current understanding of environmental factors influencing both

species, their potential interactions, and the effects of isolation on the persistence of individual cutthroat trout populations. Analysis indicated the tradeoff between isolation and invasion was strongly influenced by the size of the stream network (or cutthroat trout population) to be isolated and existing demographic linkages within and among cutthroat trout populations. Intentional isolation was predicted to benefit demographically isolated cutthroat trout populations facing certain invasion by brook trout. The relative benefits of isolation depended strongly on the size and quality of isolated habitat. Intentional isolation generally reduced the probability of persistence for migratory populations regardless of invasion threat. The BBN does not provide a decision; rather it allows a biologist or manager to explore management options within streams and prioritize conservation actions among streams with a transparent and consistent logic. It can also facilitate discussion that encourages clarification of conservation values, management goals, and biological uncertainties.

Fish Barrier Design In Northcentral Montana

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Genetically unaltered westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) in north central Montana (Missouri River Drainage) currently occupy less than 3% of their historical habitat. Declines in westslope cutthroat trout abundance and range in north central Montana are primarily attributable to hybridization with introduced rainbow trout Oncorhynchus mykiss and competition with introduced brook trout (*Salvelinus fontinalis*). In many instances protection and short term restoration of extant stocks of westslope cutthroat requires immediate suppression of brook trout and construction of fish barriers. Barrier construction has been a process of adapting various designs, which either use height or current velocity to block fish, to site conditions. Construction methods have included blasting and chipping out native bedrock, pouring concrete, anchoring of native materials, use of gabions, and installation of perched culverts. Design and funding considerations will be discussed along with advantages and difficulties associated with each barrier method. Responses of westslope cutthroat populations to blockage and removal of non-native brook trout using electrofishing has been uniformly positive and in some cases dramatic.

Effects Of Road Culverts On Eastern Montana Prairie Fish Assemblages

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Road culverts can restrict passage of fish migrating between seasonal habitats. The development of new roads, as well as the repair and upgrade of existing roads, has led to research addressing the effects culverts have on fish populations. The majority of this research has

focused on salmonid species, and the effect of culverts on movements of small-bodied, weak swimming species is largely unknown. Fish passage within a species-rich assemblage of prairie fishes was examined in two tributaries of the lower Yellowstone River having a variety of culvert types. Passage restriction at culverts was determined using a combination of existing fish passage models, mark-recapture experiments, and patterns of longitudinal fish distribution above and below culverts. Fish movement was not significantly different through culvert versus natural reaches for most species ($P > 0.05$). Additionally, few differences were observed in relative abundance and species richness above and below culvert crossings. A survey of culverts throughout much of eastern Montana showed that the conditions observed in study culverts were typical of many low-gradient, prairie streams. Many culverts had small outlet drops, low gradients, contained natural substrate, and low water velocities similar to those of natural reaches. Our results suggest that in these conditions, culverts may allow for adequate passage of most prairie species. However, more research is needed to determine what thresholds in these variables negatively influence passage of prairie fishes.

Use Of Pit Tag-Detecting Antennas To Assess Culvert Passage Of Yellowstone Cutthroat Trout And Rainbow Trout In Mulherin Creek, A Tributary Of The Yellowstone River

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Road crossing culverts create passage barriers during fish migration and, as a result, there are various tools for predicting passage success. Most tools have not been field-tested and give a "yes" or "no" answer to passage success. However, an estimate of the probability of passage could be more useful given that success is contingent on dynamic interactions of fish size, discharge, water temperature, and hydraulic conditions. We utilized half-duplex PIT (passive integrated transponder) tags to assess the probability of passage of Yellowstone cutthroat trout and rainbow trout in relation to biotic and abiotic factors among three different culvert types on a spawning tributary to the Yellowstone River. Velocities were significantly different between smooth box, baffled box and smooth circular culverts but did not differ significantly between a natural stream reach and one baffled box culvert. There was a positive linear relationship between number of attempts and velocity and a negative linear relationship between number of attempts and drop height, most likely due to culverts with lower velocity having larger drop heights. Time required for passage was inversely related to water velocity. Culverts where velocities were most similar to natural reaches allowed fish to pass multiple times in both directions and some remained in the culvert for up to 22 hr. These results show that culverts that simulate natural conditions are most efficient for allowing fish passage and that PIT tags are an efficient method for determining not only probability of passage success but also can provide measures of passage difficulty.

Fish Passage Planning And Development For Bull Trout At Thompson Falls Dam, Montana

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PPL Montana is the owner of the Thompson Falls Dam (Project), built in 1917 on the Clark Fork River near Thompson Falls, Montana. The listing of the bull trout as a threatened species under the Endangered Species Act prompted the preparation of a biological assessment (BA) to assess the impacts that the Project may be having on bull trout (*Salvelinus confluentus*), and to make recommendations about possible conservation measures to reduce those impacts. That BA concluded that the Project might adversely affect bull trout, in large measure due to a lack of upstream fish passage. An Interagency Technical Advisory Committee was established to help guide PPL Montana in their efforts to conserve bull trout by providing upstream passage. Proper location of a fish collection facility is critical to the success of an effective fish passage solution. In order to find the most effective location for the fishway, trout were radio tagged, and stationary receivers were positioned at key locations to continuously monitor fish movements. Results indicated that trout migrate upstream to the main dam, the upstream most location in the tailrace, during the early spring. Therefore, the main dam was selected as the fishway site. An alternatives analysis assessed three potential fishway configurations at that site. The Interagency Technical Advisory Committee recommended the right bank full height ladder alternative, and PPL Montana concurred. This fishway is currently being designed, and will include fish sampling facilities that will allow maximum operational flexibility for fisheries managers.

Expected Changes To The Distribution, Abundance And Life History Expression Of Fishes Following The Removal Of A Montana Hydroelectric Dam

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Milltown Dam has fragmented the Clark Fork watershed since1907. Historically, fish used large, connected, ecologically and geographically distinct habitats spanning hundreds of kilometers to express different stages of their life histories. The dam as not allowed upstream fish passage, has limited downstream fish movements and created a reservoir that has fostered a population of exotic northern pike. Recent studies show the dam's continued affect on an enormous geographic scale. Milltown Dam annually impedes migrations of tens of thousands of fish, and data suggest that fish that migrate to the dam do not spawn once their migration is impeded. Native migratory fishes like westslope cutthroat trout and bull trout have been especially affected by the dam but their annual presence at the dam suggests the potential to reestablish fluvial life history forms and enhance local or up-river populations. Milltown Dam will be removed in the next few years and the watershed will once again regain connectivity. Biotic changes from dam removal will range from drastic local changes in species composition, fish densities, and unimpeded fish passage. However, on most scales, the changes will be subtle and offer populations more resilience and better expression of life history tactics.

Restoration Plan For The Clark Fork River And Blackfoot River Near Milltow Dam

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In 2005, a consent decree set forth the terms and conditions for the removal of Milltown Dam near Bonner, Montana. Constructed in 1907 at the confluence of the Blackfoot and Clark Fork rivers, Milltown Dam is a fish passage barrier and impounds~6.6 million cubic yards of contaminated sediments transported to Milltown Reservoir from upstream historical mining in Butte and Anaconda. The State of Montana, in consultation with the Confederated Salish and Kootenai Tribes and the USDI Fish and Wildlife Service, are developing a plan that will restore the Clark Fork and Blackfoot rivers to naturally functioning, free-flowing fluvial sys-tems. Project goals include 1) maintaining water quality, 2) accommodating sediment trans-port and channel dynamics, 3) providing habitat for native fishes and other trout, 4) creating functional wetlands and riparian communities, 5) enhancing visual and aesthetic values, and 6) providing safe recreational opportunities compatible with other restoration goals. Desi ·n approaches are process and form based and include stream classification, regional hydraulic geometry relationships, regime and tractive force equations, and one and two-dimensional flow and sediment transport computations. These approaches are being used to meet both eco-logical and stability objectives. Preliminary results indicate that the most probable state of the rivers is a slightly entrenched, meandering, gravel-dominated, riffle-pool channel transitioning to a moderately entrenched channel near the confluence with the Blackfoot River. Following restoration activities, fish passage will be restored resulting in the full expression offluvial life histories for species that include bull trout, westslope cutthroat trout, and large-scale suckers.

Influence Of Migratory Barriers On Genetic Diversity And Similarity Among Bull Trout Populations In Glacier National Park, Montana

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Adfluvial populations of bull trout (*Salvelinus confluentus*) in Glacier National Park, Montana, occupy a complex landscape of interconnected and fragmented lake habitat. Natural barriers, e.g., waterfalls, may limit migration among available habitat and result in fragmentation and isolation of some populations. Polymorphic microsatellite loci were used to examine patterns of genetic diversity and similarity among populations of bull trout in Glacier National Park and to examine differences between populations isolated by migratory barriers and those occupying more interconnected habitat. One hundred ninety-six bull trout, comprising 16 populations, were genotyped at 10 microsatellite loci. Five populations were isolated by migra-tory barriers, i.e., waterfalls with a vertical drop ≥ 1.8 m. Expected heterozygosity (averaged across loci) varied from 0.18 to 0.73 among populations and was lower on average for popula-tions isolated by barriers (0.27 ± 0.09) compared to those not isolated (0.61 ± 0.08). Allelic

diversity (averaged across loci and adjusted for sample size) varied from 1.47 to 3.45 among populations and was lower on average for populations isolated by barriers (4.53) compared to those not isolated (6.46) based on a hierarchical classification. Pairwise Fst values varied from 0.00 to 0.69 with larger values representative of comparisons between populations isolated by barriers. These data indicated that natural barriers have influenced genetic diversity and similarity among bull trout populations in Glacier National Park.

Big Coulee: An Attempt To Thwart Extinction

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Westslope cutthroat trout (WCT, *Oncorhynchus clarkii lewisi*), in Big Coulee Creek were first surveyed in 1995 after the USDA Forest Service received information from Montana Fish Wildlife and Parks. Other headwater tributaries of Highwood Creek were later inventoried and it was determined that the WCT in Big Coulee were the last extant population in the drainage. Information concerning Big Coulee showed that if action was not taken quickly, this small remnant population of native fish would likely become extinct. To prevent their loss, fishery managers faced many challenges: competition/predation by brook trout, habitat degradation, and illegal angler harvest. Habitat improvement and fishery projects have been implemented to protect these aboriginal westslope cutthroat. At the end of the 2006 field season, brook trout had almost been eradicated and a fish migration barrier was successfully stopping immigration of non-native fish. The WCT population is now rebounding with dramatic increases in juveniles and adults. Due to collaborative efforts of the USDA Forest Service, Montana Fish, Wildlife and Parks, and a number of volunteers there are still WCT in the Highwood Basin.

Barrier Assessment Of The Chadbourne Diversion Dam On The Shields River

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The Shields River supports widely distributed populations of Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) that show little to no evidence of introgression with rainbow trout (*O. mykiss*) or westslope cutthroat trout (*O. c. lewis i*). The Chadbourne diversion dam, approximately 12.5 river miles upstream of the confluence with the Yellowstone River, is suspected to be a partial barrier to upstream passage of large trout. We performed a fish passage assessment of the diversion using a combination of hydraulic modeling under a range of flows combined with fish swimming and leaping abilities of Yellowstone cutthroat, rainbow, brown (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) to characterize its barrier status. We analyzed three potential passage scenarios: (1) the development of a side-channel that bypasses the diversion at high flows, (2) the potential for trout to leap over the structure, and (3) the potential for trout to pass through a keyhole or notch in the structure. Results indicate that a side-channel may form at flows exceeding the 2-year recurrence interval (RI) when the diversion is operating with wooden planks in place and a 10-yr RI when the diversion is operating without wooden planks in place. The analysis also indicated that the leap heights are too

great for all operating scenarios and flows. However, the analy is indicated that large trout of all four species might pass the structure by swimming up the key hole or notch at some flows.

Fish Losses To Irrigation Diversions ON Two Tributaries Of The Bitterroot River, Montana

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Withdrawals of surface water for irrigation and stock water leave the mainstem of the Bitterroot River and its tributaries chronically dewatered during the irrigation season. These water withdrawals affect local trout populations by entraining migratory trout in irrigation diversion canals at multiple life stages, and through the loss and degradation of available habitat for aquatic species. Irrigation losses may be responsible in part for the low abundances and restricted distributions of migratory native westslope cutthroat trout (*Oncorhynchus clarkii*) lewisi and bull trout (*Salvelinus confluentus*) in this system. Information about entrainment rates of fish into irrigation diversion canals and the factors that influence these rates is limited. Our goals were to quantify entrainment of fish into seven irrigation diversions on Lost Horse Creek and five irrigation diversions on Tin Cup Creek, two tributaries of the Bitterroot River, and to identify characteristics of these diversions that correlate with rates of entrainment. We sampled fish species by snorkeling, electrofishing, fry trapping, and reconnaissance at the end of the irrigation season at 60 sites in 2005 and 54 sites in 2006. In August, the period of peak abundances of entrained fish, we estimated 5525 fish in 2005 and 3372 fish in 2006 to be present in Lost Horse Creek diversions. We estimated 1904 fish in 2005 and 1158 fish in 2006 to be present in Tin Cup Creek diversions in August. The highest entrainment of fish occurred in canals diverting the greatest amounts of water.

Efficacy Of Fish Screens At Preventing Entrainment Of Westslope Cutthroat Trout JUveniles In Three Irrigation Canals Of Skalkaho Creek, Montana

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Fish screens have been installed to prevent fish los in many irrigation canals of the western U.S., costing millions of dollars annually. However, few studies have attempted to evaluate the effectiveness of fish screens. Our goal was to determine the efficacy of fish screens installed in three of seven irrigation canals on Skalkaho Creek, a tributary of the Bitterroot River. Fish screen efficacy was quantified using half-duplex PIT tags and PIT tag-detecting antennae located in the headgate opening(s), around the bypass pipes, and in the canal downstream from the fish screens. Throughout the irrigation eason, juvenile westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) were captured, PIT-tagged, and introduced into

each screened canal between the headgates and the fish screen. Fish screens in the Highline, Ward, and Hughes canals prevented entrainment of 97.5 percent (116 of 119), 96.7 percent (116 of 120), and 74.2 percent (72 of 97) of the PIT-tagged fish introduced into the canals, respectively. Whereas none of the PIT-tagged fish became entrained beyond the screens, 9.5 percent (32 of 336) remained in the canals upon headgate closure. Seventy-percent (21 of 30) of the PIT-tagged fish introduced into the Hughes Canal two weeks prior to headgate closure remained in the canal because no water was being bypassed and the headgates were not open enough to provide an easy upstream exit. If not rescued, fish remaining in the canal upon headgate closure would have perished. Fish screens are an effective management tool for reducing irrigation canal entrainment but their effectiveness varies among specific installations.

Seasonal And Spawning Movements Of Genetically Pure And Hybridized Westslope Cutthroat Trout In The Fan Creek Drainage, Yellowstone National Park

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Once the dominant salmonid of the Gallatin River, westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) have been reduced to four isolated headwater populations in this river drainage. We used radio telemetry to investigate the seasonal movement of westslope cutthroat trout and hybrids in the Fan Creek drainage, focusing on the North Fork. Fish were tracked for an average of 60 days throughout the summer of 2001 and an average of 262 days throughout the end of 2001 and 2002. Westslope cutthroat trout moved an average of 2143 m in the summer of 2001 and an average of 2990 meters throughout the study period of 2001-2002. The majority of movement for 2001-2002 occurred in the spring and summer months, whereas sedentary behavior was observed in the fall and winter months. R1/R4 inventory data was collected for the North Fork of Fan Creek and personal observation was used for the main stem. Westslope cutthroat trout were relocated in areas of increased instream habitat complexity and a high percentage of cover in the North Fork of Fan Creek. There was no discernable difference found in habitats where fish were relocated and where fish were not located in the North Fork of Fan Creek. In the mainstem, westslope cutthroat trout were relocated in areas where deep bends provided undercut banks and areas with root wads. In summation, fish moved throughout the Fan Creek drainage throughout the study. Adequate habitat appeared to be provided for fish to remain in the North Fork for all seasons.

Movement Of Anglers And Sediment Transport: Implications For Moving Aquatic Nuisance Species

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Movement of anglers among rivers presents a potential pathway for the spread of whirling disease and other aquatic nuisance species (ANS). The objective of this study was to quantify the movement of anglers in southwestern Montana and the quantity of sediment they

carry on angling equipment. Angler were surveyed at randomly selected high use fishing access sites on six rivers in southwestern Montana. Survey questions focused on location. of angling trips in the past 30 days, planned fishing trips for the next 7 days, equipment cleaning practices, and aquatic nuisance species awareness. In addition to the questionnaire, ediment samples were collected from boots and waders with a pressure sprayer. Mean distance traveled by Montana residents from their home to the survey site was 115 km and 1738 km for non-residents. The median number of fishing access sites used during the previous 30 days by resident and non-resident anglers was three. Non-residents fished in more states in the previous 30 days than residents and traveled further distances to fish in the previous 30 days than residents. Mean quantity of sediment carried on one boot-wader leg was 8.39 g (± 1.5, 95% CI). Combining angler movement data, sediment quantity carried, and fishing license data, anglers in southwestern Montana are potentially moving thousands of kg of soil among fishing access sites every year making transport of ANS highly likely. Control of future ANS infestations will be difficult unless sediment transport is addressed.

Effects Of Water Temperature And Angling On Mortality Of Salmonids In Montana Streams

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Effects of catch-and-release angling on salmonid mortality during periods of elevated (> 20 °C) water temperatures are largely unknown. In addition, few field studies have quantified salmonid mortality associated with angling during varying times of diel temperature cycles. Thus, our objectives were to quantify post-release salmonid mortality during elevated summer water temperatures and cooler fall water temperatures, and quantify mortality from morning and evening angling events. Angling occurred on the Gallatin and Smith rivers. Anglers were allowed to use only fly-fishing gear and techniques, without any other restrictions. Angled fish were transported from the anglers to in-situ holding cages and monitored for 72 hr. Mean rainbow trout (Oncorhynchus mykiss) mortality during summer varied from 7 percent in the Gallatin River to 9 percent in the Smith River, whereas brown trout (Salmo trutta) mortality varied from 0 percent in the Gallatin River to 8 percent in the Smith River. Mountain whitefish (Prosopium williamsoni) mortality varied from 2 percent in the Gallatin River to 21 percent in the Smith River. o mortalities for any species occurred in either river during fall sampling. Rainbow trout (n = 125) and mountain whitefish (n = 114) mortality in the Smith River differed significantly between summer and fall angling events. Different diel water tem-perature cycles between rivers likely contributed to this difference. No significant differences were detected between morning and evening angling events during the summer in either river. Currently, it appears that mortality associated with catch and release angling during elevated water temperatures (> 20 °C) is relatively low for rainbow trout and brown trout.

Environmental Conditions Affecting The Toxicity Of Piscicides

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The piscicides rotenone and antimycin are important tools in fisheries conservation but their application is inefficient and not always effective. We examined the persistence of both piscicides in the laboratory and field to determine the causes of their detoxification. The effects of sunlight and turbulence were isolated in the laboratory and studied using 96-hr toxicity tests. Sunlight rapidly detoxified both rotenone and antimycin. Turbulence affected antimycin more than rotenone. The interactive effects of combined stream characteristics were measured in streams using a single drip station and sentinel fish at 100-m intervals. Stream characteristics were measured along the entire reach that detoxified rotenone. Environmental characteristics most abundant in the stream section that detoxified rotenone were identified using logistic regression. The abundance of substrates >150-mm diameter, total dissolved solids, and oxidation reduction potential were significantly related to the persistence of rotenone in streams. The predictive ability of models was good using reclassification procedures. However, the predictive ability of the models will need to be tested in streams before they can be used in future piscicide applications. This information will make piscicide use more efficient and effective by reducing the uncertainty associated with its application.

Collection Of Samples To Detect Hybridization: One Of These Things May Not Be Like The Other

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Hybridization is an important factor to consider for the conservation of many native stream fishes. Fisheries biologists often collect samples to test for hybridization where there is ready access to stream habitats or in spatially limited stream reaches. Because stream salmonids are highly mobile animals and rapidly re-assort into mixed stock assemblages, it is often difficult to interpret the meaning of results obtained for hybridization assays at the population level. We have assayed 35 samples (n = 14-35 fish) at five codominant diagnostic microsatellite loci to determine the geographic distribution of hybrids in the Jocko River Basin. Samples were collected in 100-m sections with a backpack electrofisher. We detected hybridized individuals at only 3 of 16 sites in the South Fork Jocko River in preliminary analysis. One of those sites was non-adjacent to the other two indicating the distribution of hybrid fish in that system is variable. To design a robust sampling strategy to determine the hybridization status of a population, we assessed the spatial variability of samples in 47 stream km of the upper Jocko River drainage.

Tracki g Fluvial C tthroat Tro t Moveme t With Stabl Isotope Marker I A Stream etwork

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Movement between environments is a common phenomenon across taxa because it allows individuals to match their phenotype to the biotic and abiotic conditions that maximize fitness. However, biologists and managers did not consider movement between distinct habitats important for stream-resident fishes until recently because field methods and monitoring favored relocating immobile fish or fish large enough for tags. As a result, little is known about the frequency of movement in stream fishes and the critical locations that fishes move to within a stream network. We used stable isotope analysis to provide precise information about individual movement patterns and frequency for Bonneville cutthroat trout (*Oncorhynchus clarkii utah;* BCT) combined site-specific and trophic level-specific N isotopic signatures of BCT to estimate the frequency of movement to downstream environments, to identify downstream environments that fluvial BCT move into from headwater streams, and to identify important food resources in these habitats.

Montana Arctic Grayling: Status, Concerns, And Antidotes

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Arctic grayling (*Thymallus arcticus*) have a holarctic distribution in northern latitudes of North America and Asia. Montana Arctic grayling represent the most southerly distributed populations of the species. Species existing at the periphery of their range are often more susceptible to extinction due to habitat and environmental changes. Historic distribution and abundance of fluvial (permanently stream dwelling) Arctic grayling has decreased due to a variety of human caused and environmental factors that have imperiled the future existence of the species in Montana. The last remaining fluvial population exists in the Big Hole River representing ~ 4 percent of the native range in Montana. Population abundance and distribution of Arctic grayling in the Big Hole River has declined substantially. Assessing the factors that have contributed to the decline of grayling is essential to focus restoration efforts. This presentation will provide current population abundance, distribution, age structure, and genetic demographics of the Big Hole River grayling population. Habitat limitations, climatic fluctuations, and potential effects of non-native fishes will be evaluated with regards to grayling restoration efforts. This presentation also introduced a basin wide conservation strategy that is essential to ensure persistence of grayling in Montana.

Can Candidate Conservation Agreements Save Montana's Fluvial Arctic Grayling?

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A Candidate Conservation Agreement with Assurances (CCAA) is an agreement between the USDI Fish and Wildlife Service (USFWS) and any non Federal entity whereby non Federal property owners who voluntarily agree to manage their lands or waters to remove threats to species at risk of becoming threatened or endangered receive assurances against additional regulatory requirements should that species be subsequently listed under the Endangered Species Act (ESA). The goal of the Big Hole CCAA is to secure and enhance a population of fluvial Arctic grayling (*Thymallus arcticus*) within the upper reaches of their historic range in the Big Hole River drainage. Under this Agreement, Montana Fish, Wildlife and Parks (MFWP) holds an ESA Enhancement of Survival Permit issued to it by USFWS and will issue Certificates of Inclusion to non Federal property owners within the project area who agree to comply with all of the stipulations of the Agreement and develop an approved site specific plan. Site specific conservation plans will be developed with each landowner by an interdisciplinary technical team made up of individuals representing MFWP, USFWS, USDA Natural Resources Conservation Service, and Montana Department of Natural Resources and Conservation. The conservation guidelines of the Big Hole CCAA will be met by implementing conservation measures that 1) improve streamflows, 2) improve and protect the function of riparian habitats, 3) identify and reduce or eliminate entrainment threats for grayling, and 4) remove barriers to grayling migration. We believe this program represents the best opportunity to conserve the Big Hole River grayling population.

The Restoration Of The Upper Big Hole Watershed's Riparian And Instream Habitat Using Candidate Conservation Agreements

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The Candidate Conservation Agreement with Assurances (CCAA) for fluvial Arctic grayling (*Thymallus arcticus*) in the upper Big Hole watershed presents a unique opportunity to develop and implement comprehensive restoration and conservation projects on private land. During the preliminary sing-up in 2005, 40 landowners enrolled just under 220,000 ac of private land, representing nearly 70 percent of the private land in the project area. Site-specific restoration plans for each property, which addresses everything from instream and riparian restoration, grazing management, irrigation efficiency improvement, off-stream livestock water development, entrainment and fish passage, need to be developed with consideration of the unique physical and hydrologic characteristics of each property, as well as the agricultural goals and objectives of each livestock operation. The cumulative effects of restoration on one property upstream have tremendous ramifications downstream. The scale and complexity of this undertaking, the largest of its kind ever developed in the country, relies upon the dedication and creativity of many valuable partners.

Improving Stream Flows IN The Upper Big Hole Using Candidate Conservation Agreements

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Stream flow improvement is a key conservation guideline outlined in the andidate Con-servation Agreement with Assurances (CCAA) presently being implemented for fluvial Arctic grayling (*Thymallus arcticus*) in the Big Hole River drainage. Eight years of drought conditions, over-appropriation of water rights, and dependence on the beneficial use of its water for irriga-tion, presents a water management challenge for agencies and CCAA enrollees in the upper BigHole basin. The Montana Department of Natural Resources and Conservation (D RC) provides technical support to meet this challenge through quantification and assessment of basin hydrol-ogy, water use, and water management practices. Data have been collected from an established flow monitoring network, tributary and mainstem synoptic stream flow measurement runs, and water rights compliance checks. These data helped establish flow conditions prior to the implementation of the CCAA and provide the basis for understanding the timing and magnitude of water use and its influence on stream flows. Water savings to be converted to stream flow are anticipated through CCAA-associated activities with landowners such as supplemental flow agreements, infrastructure improvements, irrigation management planning, and water rights compliance. While it will take years to fully implement all facets of the CCAA water manage-ment goals, improvements to river flows have already been realized. Between 2003 and 2006, increases in river flows relative to water availability were documented. These increases can be attributed to voluntary flow reductions by irrigators. Irrigator cooperation such as this will need to continue to ensure the success of stream flow improvement using the CCAA.

Understanding Entrainment Dynamics And Potential Implications To The Conservation Of Arctic Grayling In The Big Hole River

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Arctic grayling (*Thymallus arcticus*) in the upper Big Hole River watershed display signifi-cant migratory patterns, and as such, are susceptible to becoming entrained in irrigation ditches during their annual migrations. The extent of entrainment and its impact to the population, however, is poorly understood. To gain insight into entrainment dynamics in the Big Hole River watershed, survey and salvage efforts were conducted in 2006. We completed electrofishing sur-veys on approximately 2 percent (42.5 mi) of the irrigation ditches owned by landowners that have enrolled in the Big Hole Grayling Candidate Conservation Agreement with Assurances (CCAA) Program. One of the CCAA conservation goals is to assess and minimize the effects of entrainment on the grayling population. In 2006, five adult grayling were captured in irrigation ditches. This represents 12 percent of all adult grayling that were captured during annual fall population monitoring efforts by Montana Fish, Wildlife, and Parks in 2006. The implication of these findings and previous efforts are discussed in relation to their potential effects on grayling population abundance and recovery efforts. Strategies to minimize entrainment may include the installation of fish screens, changes to irrigation infrastructure, and voluntary flow reduc-tions. Implications of these actions are also discussed in terms of their potential impact on water rights, pending water rights legislation, and the Big Hole Grayling CCAA.

Grayling Reintroduction In The Ruby River, Montana

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The Arctic Grayling Workgroup designated the Ruby River as a potential restoration site for fluvial arctic grayling (*Thymallus arcticus*) based on an assessment of historic grayling streams in Montana. The Ruby was chosen among candidate streams because of its long sections of unimpeded stream, suitable habitat conditions, and relatively low densities of non-native salmonids. Potential negative characteristics of the Ruby include access to Ruby reservoir, and the presence of non-natives. Reintroduction efforts began in the Ruby in 1997 following the 1995 Grayling Restoration Plan. Grayling derived from the Big Hole River were stocked as age-one and young-of-the-year. Natural reproduction of stocked grayling was documented two different years, indicating suitable habitat was available; however, high over-winter mortality rates illustrated the need for an alternative to stocking. Reintroduction efforts have evolved from stocking, to the use of Remote Site Incubators (RSIs) which emerge grayling fry reared under selective mechanisms of the stream. RSIs have been used since 2003 and have been very successful at introducing grayling to the system. Over-winter survival of grayling from RSIs has been documented 3 yrs in a row. Habitat enhancement projects to increase adult pool, spawning, and rearing habitat for grayling are now complimenting RSI efforts. Future direction of Ruby reintroductions will be determined by current revision and updating of the Grayling Restoration Plan. This plan will revisit restoration goals, provide genetic and brood stock management direction, and create short and long-term goals that address connectivity, habitat, and population goals for grayling in Montana.

Changes In Angler Use Following An Unauthorized Walleye Introduction In Canyon Ferry Reservoir

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Angler use of Canyon Ferry Reservoir has changed following an unauthorized walleye (*Sander vitreus*) introduction. In summer 1986 majority of anglers targeted rainbow trout (*Oncorhynchus mykiss*) (81.9%) and fished from the shoreline (62.9%). It took an average time of 96 min for an angler to catch any species of fish. Following expansion of the walleye population in the late 1990s, the majority of anglers in 2005 target walleye (69.2%) and fish from boats (83.2%). In 2005 it took an average of 399 min to catch any species of fish. Total angler pressure has decreased from 98,768 angler days in 1989 to 80,249 angler days in 2005. Angler origin has changed little since walleye introduction with Lewis and Clark, Gallatin, and Broadwater Counties representing most anglers. Percent of out of state anglers have decreased from a peak of 10.7 percent in 1987 to a low of 2.3 percent in 2004. Walleye contribute little to the winter fishery, however heavy predation of yellow perch (*Perca flavescens*) has led to declines in winter angler pressure. With declines in perch numbers, rainbow trout have become the primary component of the winter fishery. Since the introduction of walleye the Canyon Ferry fishery has become less accessible to general and shoreline anglers. Predation by walleye has reduced numbers of other sport fishes in the reservoir to the point that walleye are currently the only sport fish that meets management goals.

Effects Of Spill On The Kootenai River Below Libby Dam In 2006

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Mismanagement of reservoir elevations in the spring of 2006 caused forced spill to occur from Libby Dam on the Kootenai River from 8 June 2006 to 27 June 2006. Spill discharge reached a maximum of 31,000 ft^3/sec (cfs), leading to the highest discharge of 55,000 cfs from Libby Dam since regulated flows began in 1974. Spill discharges above approximately 1200 cfs cause gas supersaturation and subsequent violation of the state and federal water quality standards of 110 percent. Gas levels reached a maximum of 133.5 percent and the 110 percent saturation level was exceeded for 18.5 consecutive days (446 hrs) below the Dam. Initially, higher percentages of fishes exhibited gas bubble trauma symptoms on the left bank when compared to the right bank, but after 14 days of spill, 93.0 percent of rainbow trout, 82.0 percent of mountain whitefish, and 100.0 percent of bull trout exhibited symptoms of gas bubble trauma. No mass mortality of fishes was seen in the river below the Dam, with the exception of kokanee that passed over the spillway. The long term effects on fishes below the dam are unknown at this time, but monitoring will continue in the spring of 2007 for rainbow and bull trout populations, downstream displacement of PIT tagged fishes, and genetic analysis of the bull trout population using pre and post spill genetic analyses.

Correct Implementation Of Variable Flow Flood Control (VARQ) At Libby Dam During 2006 Could Have Avoided Spill And Prevented Impacts To Kootenai River Fish

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The variable flow flood control strategy (VARQ) was designed to improve conditions for resident fish species including the endangered Kootenai white sturgeon (*Acipenser transmontanus*) and threatened bull trout (*Salvelinus confluentus*) while dam operations are modified to recover ESA-listed anadromous fish species in the lower Columbia River. Failure to follow VARQ at Libby Dam during 2006 caused an uncontrolled spill and flooding in the Kootenai River. As much as 31,000 ft^3/sec (cfs) was released through the spillway, exceeding Montana's water quality standard of 110 percent gas supersaturation for 19 days. Gas levels reached a maximum of 133.5 percent causing gas bubble trauma in Kootenai River fish. Flood stage at Bonners Ferry, Idaho, was exceeded, causing some stakeholders in the US and Canada to doubt the effectiveness of this flood control strategy. The U.S. Army Corps of Engineers considered abandoning VARQ and reinstating standard flood control practices. Analysis of the event revealed that the Corps' discharge protocol had not been implemented as designed. Dam discharge during April and early May was therefore insufficient to control the slightly-above-normal inflow. Spill, flooding and gas bubble trauma in Kootenai River fish could have been avoided if VARQ had been implemented as designed.

Investigations Into Rapid Temperature Decreases In The Upper Madison River Downstream From Quake Lake, Montana

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During the review of temperature data collected from the Madison River downstream from Quake Lake, we noticed two cases of short term, very sharp temperature decreases. On 23 June 2001, river temperature decreased 8.1 °F over 7.5 hours and on 28 July 2001, river temperature decreased 15.2 °F over 9.5 hrs. Water temperature remained low for ~ 30 min to 1 hr and then rebounded quickly to typically normal levels. We believe that the cause for these anomalies may be a wind driven disturbance tilting the Quake Lake thermocline allowing cool hypolimnetic water to spill out of the Quake Lake outlet. We support this hypothesis with a presentation of the geographical orientation of the Lake, wind data from a nearby weather station, and temperature profile data taken from Quake Lake. Other cases of this phenomenon at this site are identified.

Estimation Of Fish Age Using Otolith Relative Mass

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Otolith and body growth rates are non proportional, resulting in fast growing fish with relatively small otoliths at a given body size and vice versa. Thus use of otolith mass alone to estimate fish age will be biased when body growth rates vary from those in the established age versus otolith mass relationship. By accounting for the otolith mass at a given body size (defined as otolith relative mass) it should be possible to improve age models particularly when growth rates are variable. Herein I compared two multiple regression models incorporating otolith relative mass to predict Flathead Lake lake trout (*Salvelinus namaycush*) annuli with a conventional otolith mass regression. I found that the models incorporating otolith relative mass were less prone to growth bias, and produced growth curves that better mimicked the empirical relationship. The best performing otolith relative mass model was applied to archived otoliths, revealing a pattern of sharply declining growth from 1986-1991 to 1998, and a smaller decline from 1998 to 2005. Coherent with these temporal growth declines I observed increases in otolith mass at a given body length, suggesting that the otolith mass vs. body length relationship can be used to monitor growth rates.

A New Biochemical Genetic Technique To Examine Hybridization Among Westslope Cutthroat, Yellowstone Cutthroat, And Rainbow Trout

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Hybridization is a large threat to the continued existence of native cutthroat trout (*Oncorhynchus clarkii*). Considerable effort has been spent identifying and attempting to conserve non-hybridized native cutthroat trout populations. Previously, Montana Fish, Wildlife, and Parks used a procedure examining fragments of nuclear DNA located between transposable elements (PINE analysis) to determine whether or not populations were hybridized and to what extent. A problem with this technique was that the markers used were inherited in a dominant/recessive fashion making identification of all genotypes not possible which from a statistical aspect weakens the power of the data. We developed a procedure that examines codominant insertion/deletion (indel) events as well as microsatellite markers that distinguish among westslope cutthroat (*O. c. lewisi*), Yellowstone cutthroat (*O. c. bouvieri*), and rainbow trout (*O. mykiss*). The codominant nature of these markers allows for the direct determination of all genotypes and estimates of allele frequencies in samples which greatly increases the power of the data. Furthermore, the new procedure requires only two independent polymerase chain reactions which reduces the amount of effort required to collect the data. This technique, therefore, is far superior to the previously used PINE analysis.

Evaluation Of Stocking As A Means Of Replacing Introduced Trout Populations In Lakes With Westslope Cutthroat Trout

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Conservation and restoration plans often call for the elimination and replacement of nonnative fish populations. Elimination in lakes has generally been successful only by poisoning. Poisoning is becoming increasingly problematic, however, because of legal and permit issues and potential social and political opposition. As an alternative to poisoning, we investigated the effectiveness of stocking as a means of replacing nonnative lake populations of trout. Among six lakes in the South Fork Flathead River drainage, Montana, genetic analysis indicated after stocking began that the proportion of westslope cutthroat trout (*Onchorhynchus clarkii lewisi*), alleles had progressively increased from zero, or near zero, to 0.75 up to 0.99. Some of this increase was due to hybridization and introgression with the stocked fish. Examination of individuals, however, indicated that most of the change was due to the replacement of fish in the lake with westslope cutthroat trout. The results suggest that in small headwater lakes with limited spawning and juvenile rearing habitats stocking juveniles can be an effective means of replacing introduced nonnative trout populations or hybrid swarms with westslope cutthroat trout.

Who's Yer Daddy? Photo Documentation Of Bull Trout And Brook Trout Hybridization

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Field survey and genetic sampling of fish in Goat and Lion Creeks, two tributaries of the Swan River in northwest Montana, indicated hybridization between bull trout *(Salvelinus confluenlus)* and brook trout *(S.jontinalis).* In 2006 I used an easily-constructed Plexiglas streamside solarium and a digital camera to individually photograph each of336 Salvelinus specimens that were randomly captured by electrofishing crews at five sites in the two drainages. Finclip samples from each fish were analyzed, using a set of 13 microsatellite loci previously identified as being useful to distinguish between bull trout, brook trout, and hybrid individuals. Preliminary results of the genetic analysis determined that about 53 percent of sampled fish were bull trout, 38 percent were brook trout, and 9 percent were hybrids. Field identification matched closely with these proportions and well-trained observers adequately identified hybrid specimens. However, nine field misidentifications that were detected by genetic analysis were correlated to hybrids; some due to inability to recognize larger fish(> 200 mm) as hybrids, and several due to smaller brook trout(< 100 mm) that were improperly identified as hybrids. Additional evaluation of the genetic attributes of hybrid individuals will determine more about individual ancestry and spatial and temporal patterns of hybridization. The unique archive of broadside digital photos of which most provide good or excellent representation of phenotypic characteristics, will allow us to use "visual virtual recall" to re-examine phenotypic characters of each fish. e.g., coloration and spotting patterns, and may be useful as future training aids.

Considering Natural Vegetation Development Processes In Streambank Stabilization Design

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Stabilizing eroding streambanks is a common component of stream and river restoration projects and is addressed by various disciplines using a wide range of techniques. A native species revegetation approach to streambank stabilization has numerous benefits and is being used with increasing success in western Montana. The most successful streambank stabilization efforts combine techniques from the tool boxes of different disciplines, such as incorporating soil bioengineering techniques with natural channel design structures like log vanes and engineered log jams. In addition to improving channel function and stability, including native species revegetation as part of streambank stabilization accounts for ecological processes necessary for long-term self-maintenance of restoration projects. Ecological processes that influence vegetation development along streams include alluvial bar deposition, plant community succession and related soil development, surface water/groundwater connection, and wildlife influences such as deer browse and beaver dams. Considering different vegetation development pathways in the context of these processes will result in streambank stabilization efforts that are self-sustaining and support objectives for instream habitat, riparian revegetation, and dynamic stability at the reach scale.

Dual-Frequency Identificatio Sonar (DIDSON) For Fisheries Applications: Cool Tool Or Expensive Toy?

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The Dual-Frequency Identification Sonar (DIDSON) camera was developed for inspec-tion and identification of objects underwater in highly turbid environments, using acoustic lenses and sonar technology to deliver near video-quality images. Although developed primar-ily for the avy to image underwater structures, such as mines and ship hulls, the DIDSO is now available to the public and is being used for other applications. Reclamation has been exploring the technology to determine if it can provide a useful tool for fisheries management. The DIDSO camera operates using sound frequencies and allows observations of fish behav-ior in large, turbid rivers where video camera observations are impossible, and is also useful in identification of substrates and observation of other underwater structures. Reclamation has captured images of razorback sucker (*Xyrauchen texanus*) spawning behavior in the Colorado River and is currently using the technology on the Yellowstone and Missouri Rivers in hope of documenting behavior of the endangered pallid sturgeon (Scaphirynchus al bus) and other native fish. Preliminary results are promising. We found that the best image quality is obtained by deploying the camera on a remote controlled underwater tripod. The most effective meth-ods are either using the camera in conjunction with radio telemetry to locate a known target or by setting the camera in favorable habitat and waiting for fish. Though there are some limita-tions, DIDSON technology may provide a useful tool for fisheries applications.

Spawning Abundance Of Bull Trout In Relation To Geomorphology, Temperature And Roads IN TributarieS Of Rock Creek Basin (Missoula And Granite Counties), Montana

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Land management is a pervasive influence on imperiled native aquatic species, but its effects are often difficult to tease from those of natural environmental variation To discriminate these effects, we first indexed bull trout (*Salvelinus confluentus*) spawner abundance from redd survey counts made in 19 tributaries of Rock Creek—Upper Clark Fork Basin, Montana (Missoula and Granite Counties). We compared response metrics of pawner abundance against a large suite of environmental variables, including measures of geomorphology, summer stream temperature and land management. We iterated multivariate analyses to compare effects of alternate aggregation and stratification methods for both response and environmental variables. Significance tests revealed several robust results: spawner abundance increased with channel or sub-basin slope, declined with maximum stream temperature, increased with proportion of sub-basin in wilderness and roadless area, and increased with extent of bounded alluvial valley geomorphology. Catchment road density did not correlate with bull trout spawning, but the range of road density among Rock Creek sites was one order of magnitude lower than in a previously published analysis for Swan River tributaries (Baxter et al. 1999). The two studies showed highly consistent associations with catchment and stream hydrogeomorphic features. We hypothesize that proportional roadless area, a variable that reflects

the dispersion of road disturbance within the catchment, is an important factor at low road density, but at moderate and higher road densities prevailing across the bull trout's range, total road density tends to saturate or override the effect of spatial distribution of roads within the catchment.

Eustache Creek Mine Site And Stream Channel Reclamation-Planning, Monitoring, And Implementation

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Mining for gold in middle and headwater tributary streams of the Ninemile Creek watershed, a middle Clark Fork River tributary, has left numerous physical and biological legacies slow to heal. These legacies include unstable channel and floodplain habitats, an inhibited riparian community, increased water temperatures, reduced stream channel complexity, disconnected surface flow and altered fish assemblages. Large-scale fire and landscape scale evaluations in Ninemile watershed provided the planning backdrop for prioritization, partnership, and implementation of the Eustache Creek project, a 1-mi reclamation project in the headwaters of Ninemile Creek. Reclamation objectives include: provide bedload transport through the reach by facilitating deposition and scour without excessive aggradation or degradation, increase channel complexity (wood, pools, substrate), re-watering dewatered channel segments, and improving the ability of floodplain surfaces to support primary and secondary succession of native vegetation. We used a geomorphic design approach to establish stream channel and floodplain configurations in an attempt to achieve these objectives. Restoration techniques included collection and propagation of native riparian seed for transplant back to reclaimed surfaces, use of shallow groundwater retention sills, rootwad composites and wood vane structures to assist with initial channel stability and complexity, and organic amendments to mine spoils. No large rock was imported to fix the channel in place. Pre- and post-project monitoring includes longitudinal and cross-section profiles, fish abundance and movement estimates, aquatic invertebrate metrics, water temperature monitoring, instream habitat metrics, and photo points in both the reconstructed and a reference tributary similar to Eustache Creek. Preliminary findings were discussed.

Hebgen Reservoir Activities Update: Still Looking At Factors That Could Potentially Be Limiting Wild Rainbow Trout Recruitment To The Hebgen Fishery

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Seldom does a lake or reservoir environment contain sufficient spawning and rearing habitat to support a self-sustaining fishery and maintenance of the sport fishery is achieved through stocking. Hebgen Reservoir, however, is rare among reservoir systems. Numerous tributaries with in the Hebgen system provide high quality spawning and rearing habitat. Brown trout Salmo trutta have been self-sustaining since 1956, and spawning runs of wild rainbow trout (*Oncorhynchus mykiss*) occur in nine Hebgen tributaries. In 2002 a graduate research project

investigated tributary potential for recruitment of wild rainbow trout. Results of the study suggested that quantity and quality of spawning and rearing habitat was not likely limiting wild rainbow trout production, but other factors in the tributaries and reservoir may be affecting recruitment to the adult population. Therefore, upon recommendations of the 2002 tudy, Montana Fish, Wildlife and Parks in conjunction with the Gallatin ational Forest initiated investigations to identify other factors within tributaries and the reservoir that may be influencing wild rainbow trout survival and recruitment to the adult population in the Hebgen Basin.

Population Structure And Seasonal Habitat USe Of The Northern Pike Population Of Cabinet Gorge Reservoir, Montana

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Northern pike (*Esox lucius*) have been shown to impact salmonid communities in many areas where this predatory species has become established. The potential for such impacts to limit the effectiveness of native salmonid management and mitigation programs for abinet Gorge Reservoir and its tributaries provided the impetus for this study. This study employed active and passive capture techniques to characterize the northern pike population and to provide fish for radio-tagging. A total of 51 northern pike were radio-tagged and tracked over the course of this study (Apr 2003-Jul 2005) to ascertain habitat use and possible overlap with native salmonids. Telemetry depicted northern pike closely associated with shallower habitat characterized by abundant aquatic vegetation. Hard part aging found most northern pike captured were between 4 and 6 yrs of age. Proportional stock density and relative weight indices averaged 85 and 141, respectively. Opportunistic angler urveys portrayed a northern pike-based recreational fishery of increasing popularity. Extensive efforts to document reproduction suggested that water level fluctuations negated successful spawning. Although no bull trout Salvelinus confluentus or westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) were found in 66 stomachs sampled or 19 instances when gastric lavage was performed, the preponderance of northern pike detections in Bull River Bay represented a significant opportunity for predation of migratory native salmonids from this important nursery tributary. Based on the history of impacts northern pike have had on native salmonids in other systems, possible corrective fisheries management measures may be warranted.

Biological Sciences – Terrestrial

Abstracts of the 2007 Annual Meeting of the Montana Chapter of the Wildlife Society

Developing Energy, Sustaining Natural Systems: How Do We Do It?

February 6-9, 2007

Bozeman, Montana

Introduction

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The Montana Chapter of The Wildlife Society is the professional association of biologist active in wildlife research, management, education, and administration within the State of Montana. The goal of the Chapter is scientific management of Montana's wildlife resources and their habitats. The principle objectives of the Society are: (1) to develop and promote sound stewardship of wildlife resources and of the environment upon which wildlife and humans depend; (2) to actively participate in programs designed to diminish human-induced environmental degradation; (3) to increase awareness and appreciation of wildlife values; and (4) to seek the highest standards in all activities of the wildlife profession. Society members are dedicated to sustainable management of wildlife resources and their habitats and ecology is the primary scientific discipline of the wildlife profession. The Society also believes that wildlife, in its myriad forms, is basic to the maintenance of human culture and quality of life.

To further explore the public trust in our times, the 2007 conference theme was Developing Energy, Sustaining Natural Systems: How Do We Do It? We toured the energy scene, including various types of energy development, the regulatory framework, wildlife/habitat impacts, and the long term forecast. What started as a pre-conference training workshop, Energy 101, continued into a series of special energy sessions throughout the main conference in unprecedented fashion, reflecting the importance of the topic and implications for Montana's wildlife. Featured speakers included professionals from Alberta and Wyoming who clearly demonstrated the challenges of balancing wildlife conservation and energy development. Other speakers working at the wildlife – energy interface covered topics including energy transmission corridors, wind development, coal development potential, sage grouse, bats, mule deer, and habitat mitigation strategies. The Plenary Session was a lively series of presentations that touched on a wide array of perspectives about energy development in Montana.

A second workshop entitled Building Connections between Wildlife Populations and People: The Application of Wildlife Linkage Across the Northern Rockies Landscape addressed the critical issue of how to assure movement opportunities for wildlife as human development proceeds, human populations increase, and energy resources are developed. A third workshop brought people together for a dialogue on children and nature: No Child Left Inside, Reconnecting Montana's Youth to Nature. Children today spend less time outdoors than

in past generations and that has important implications for ensuring conservation successes and instilling stewardship values in future Americans.

One of the featured speakers was Dr. Steve Running from the University of Montana, whose participation on the United Nations Intergovernmental Panel for Climate Change would garner the 2008 Nobel Peace Prize. His presentation was titled "Climate Trends and Ecosystem Responses in Montana." While science is a phenomenally slow process and uncertainty remains, Dr. Running challenged us to really think about climate change and it implications for Montana wildlife as we design protocols and collect data, make management decisions, and plan habitat conservation projects, among other things

The Montana Chapter herein provides the abstracts of its 2007 Annual Meeting. Many reference ongoing research and management projects, and may include data that are not comprehensive or fully analyzed. Thus, abstracts should not be cited in other works without permission of the author(s), whose contact information is provided Our next annual meeting will be held 26-29 February 2008: Northwest Connections: Sustaining our Wildlife Popula-tions in the Face of Climate Change, Human Population Growth, and Energy Development.

A Blueprint for Energy Self-Reliance: How All of Montana's Energy Needs Can Be Met Using Conservation and Clean, Renewable Energy While Creating Jobs, Saving Money, and Revitalizing Rural and Urban Communities

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Montana stands at a crossroads. Right now, in 2007, efficiency combined with renewable, clean sources of energy cost less, and can be brought on line faster than any new sources of fossil energy. AERO's vision is that Montana can prosper with an energy policy based entirely on conservation and renewable resources. It is both technically and financially feasible to do this. We can grow our economy without damaging our air, water, land or quality of life and without spewing further greenhouse gases into Earth's atmosphere. Doing this right means developing diverse and decentralized energy systems, creating meaningful work for our citizens, broadening local ownership of production and distribution systems, reducing our vulnerability to natural or human-caused disasters, and enhancing the resilience and well-being of our rural and urban communities. The first and by far the cheapest thing to do is efficiently manage energy demand, do more with less. Then do the rest with renewable sources of energy. AERO wrote the blueprint document to catalyze citizen participation in creating a sound statewide energy policy. The choices we face are political, not technical. It is our money and our environment. We can use Montana's renewable resources effectively to supply all of our state's internal energy requirements now and into the future. We prefer this to the conventional scenario of continuing as an energy colony, extracting non-renewable resources and shipping them out or, in the case of coal, burning it here and polluting our air, water and soil in order to create electrons to be transmitted elsewhere. We believe Montana's best contribution to the nation will be to assume a new role, as a regional model of clean energy, self-reliance and true "homeland" security.

Developing a Monitoring Framework for Wolves in Idaho

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Since wolf reintroduction, radio telemetry has been the primary tool for monitoring wolves in Idaho. However, its efficacy as the sole method for population monitoring will wane as the wolf population expands and federal funding for wolf management diminishes. Maintaining radio-collared wolves dispersed widely across the landscape is an expensive and logistically difficult monitoring approach. Few studies, however, have developed reliable alternatives for monitoring wolves across varied landscapes. We are evaluating the effectiveness of wolf population monitoring methods within four separate study areas in Idaho. One method, the summer scat method, stratifies habitat to facilitate sampling, provides data indicative of reproduction, and can provide estimates of wolf abundance. We are also testing the efficacy of hunter questionnaires and public sightings in estimating wolf abundance in the study areas. In addition, we are pilot testing several novel methods to detect and count wolves. To provide a statewide assessment of wolf distribution and abundance, we will collate data from tested non-invasive field methods, public observation data, and radio-collared animal data into an occupancy model. Preliminary analyses indicate an occupancy model using only public sightings can reasonably estimate number of wolf packs in Idaho. Development and refinement of such an occupancy model provides a framework for wolf population monitoring in the absence of, or complementary to, intensive telemetry-based monitoring. We expect our findings will be of interest and wholly applicable to professionals who manage wolf populations in other states.

Ten Years of Wolf-Ungulate Dynamics in the Madison-Firehole Drainage of Yellowstone National Park

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Patrick J. White, Yellowstone Center for Resources, Yellowstone National Park, Wyoming 82190

This study utilizes long-term research on a tractable and relatively unexploited wolf-elk-bison system in central Yellowstone, from 1996 to 2006, to investigate wolf recolonization dynamics, predation rates, and prey selection. Employing a combination of ground-based radio-telemetry and ground-tracking and monitoring methods, > 670 kills, 1400 locations, and 3200 km of tracking data were amassed from multiple wolf packs preying on a resident elk herd and a migratory bison herd. The ratio of wolves to ungulates is possibly the highest predator-prey ratio ever recorded, as wolf density, space use, and predation pressure in the study area increased dramatically before sharply dropping in the winter of 2006. Wolf use of the study area increased from a few itinerant wolves, to multiple established packs, before decreasing to primarily one pack. Elk comprised the preferred prey for wolves, and the ratio of preferred to alternative prey was predictably variable, both within and between winters, as bison migration

occurred. onsiderable variation in wolf predation rates was also demonstrated, both within and across years and packs. Prey selection trends demonstrate that wolves are increasingly utilizing bison as prey, such that bison comprised the majority of wolf diets in winter 2006. The potential implications of this on future wolf-ungulate dynamics are addressed.

Do Natural Gas a d Wildlif Mi ? Eval ati g Ef e t of E ergy Develop me t o Pro ghor Wester Wyo ii g

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The Upper Green River Valley in western Wyoming is home to >100,000 wintering ungulates as well as 30-50 trillion cubic feet of natural gas. In 2005, we initiated a 5-year study to assess the effects of habitat loss, fragmentation, and human disturbance associated with gas-field infrastructure on pronghorn habitat use, movements, and demography. Data on survival, habitat use, and daily/seasonal movements are being collected with GPS collars (n= 50) that provide up to 8 locations/animal/day. Beginning in 2007, data from GPS collars will be supplemented with 100 VHF collars to provide more robust estimates of survival. In addi-tion, we are contrasting correlates of reproduction such as body mass, stress hormones, and pregnancy rates between experimental animals that primarily winter in gas fields and control animals that reside in undeveloped areas, and are collecting data on bio-physical factors, e.g., snow depth, that influence pronghorn distribution. Preliminary results indicated that control and experimental animals had no differences in survival rates, body mass, or fecundity, sug-gesting that proximity to development has no detectable effe ct on pronghorn demography. Snow depth in excess of ~20 cm has an overriding influence on pronghorn use of local habitats. However, independent of snow depth, pronghorn tend to avoid areas that are fragmented by gas fields and roads, especially habitat parcels less than 600 ac in size. Ultimately, our results will enable industry and agencies to understand how energy-related footprints affect landscapes and population-level responses.

Road and Landcover Characteristics Affecting Deer Highway Crossings a d Mortality along U.S. Highway 93 on the Flathead Indian Reservation, Montana, USA

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Animal vehicle collisions (AVCs) affect people and wildlife. On the Flathead Indian Reservation in western Montana, in an effort to reduce AVCs and increase highway safety, federal, state and tribal governments agreed to reconstruct the main highway through the reservation for the safety of travelers, but with considerations for cultural resources including wildlife. In this study we investigate road and land-cover characteri tics associated with deer (*Odocoileus spp.*) collision and crossing locations preceding highway recon truction effort

Deer movements across the highway corridor were obtained from deer mortality records of highway accident and carcass removal reports; and live deer highway crossing locations from an associated tracking study. A geographic information system was used to determine proportions of landcover variables within three spatially buffered layers centered on U.S. 93. Binary logistic and multiple linear regressions were used to evaluate models, and Akaike's Information Criterion (AIC) was used to rank models and variables. The results showed that landcover variables could be used to predict crossing or kill location. Top predictors included a positive correlation to forest cover, distance to the nearest city, and low intensity residential development. Negative correlations were found for distance to nearest water and population density. Results of this project will be used for comparison to post-construction movement patterns.

The Bird Community in Beetle Outbreak Areas: Surveying for Black-Backed Woodpeckers and Other Species

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Most avian distribution studies in Montanan conclude that black-backed woodpeckers are relatively restricted to post-fire areas. However, some studies elsewhere in the West have located black-backed woodpeckers in beetle outbreak areas. During the summer of 2006, the Landbird Monitoring Program, a collaborative effort between the Avian Science Center and the USDA Forest Service, surveyed for birds via point counts and surveyed for woodpeckers via broadcast callers to assess the bird community in beetle outbreak areas. We used GIS and grid-based, off-road sampling design to determine study sites and surveyed on five National Forests. We found very few black-backed woodpeckers associated with beetle outbreak areas. However, the bird community was varied and other species appeared to respond to the presence of beetles. Additionally, because the ASC also conducted a concurrent, near identical study in post-fire habitats, we compared detections of black-backed and other woodpecker species between these different habitats. We highlight these findings, discuss plans for upcoming field work, and provide details of current Avian Science Center happenings.

A Habitat Conservation Network Based Upon Focal Species: Design for The Inland Rainforest of North America

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A conservation plan should maintain ecologically functional populations of native plants and animals across large regions. In planning for the 194,799 km^2 Inland Temperate Rainforest (ITR) of British Columbia, Montana, Idaho, and Washington we focused on three animal groups: terrestrial wildlife, aquatic species, and birds. Terrestrial wildlife conservation requires core secure habitat large enough to maintain populations of large carnivores. These

species serve as umbrella species for other less sensitive animals. We developed terrestrial habitat suitability models for grizzly bear, wolf, wolverine, lynx, cougar, and mountain caribou. Results identify habitat cores for each of the six focal species that were merged into optimal composite cores to meet needs for several species. Optimized cores cover 102,326 km^2 or 52.52 percent of the ITR. Of this, 17,847 km2 or 17.44 percent of the cores was non-habitat. Habitat cores thus comprised 42.44 percent of the ITR. Least-cost-path connectivity method-ology identified probable movement corridors between cores. Secondly we modeled aquatic species habitat based on the work of chris Frissel. Optimal terrestrial wildlife cores included most of the best aquatic habitats. Highest quality watersheds mostly within the optimized cores added an additional 4,584.04 km2 of area to the network, or 2.35 percent of the ITR. Thirdly we used bird richness models developed by Andy Hansen to prioritize avian specie. habitat. Over 50 percent of the best avian habitats were included within the terrestrial core solution. This broad-scale habitat network comprised 44.79 percent of the ITR: this guides site-specific conservation solutions at finer scales which integrate into the overall design. design.

Contaminants in Eggs of Lesser Scaup Nesting on Lower Red Rock Lake, Red Rock Lakes National Wildlife Refuge

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North American lesser and greater scaup (Aythya affinis and A. marila, respectively) have declined at a rate of nearly 150,000 birds/yr for the last 25 years. Band recoveries indicated lesser scaup breeding in southwest Montana at Red Rock Lakes National Wildlife Refuge (Refuge) have one of the shortest migration routes of North American scaup (<1100 km), and winter in areas known to have elevated levels of contaminants. This led to concerns that contaminants obtained on wintering grounds could be negatively affecting scaup productivity on the Refuge. In 2006 lesser scaup eggs were collected on the Refuge from nests located in wetland habitats of Lower Red Rock Lake. Eggs were analyzed for organochlorine (OC; n 25) and metal (n = 10) concentrations. Egg contaminant levels were regressed against initiation date to examine contaminant depuration rates during the breeding season. Only one OC analyte, p,p'-DDE, was detected in all 25 egg samples, four analytes were detected in 4-56 percent of the samples, and 17 analytes were not detected. Geometric mean concentration of p,p'-DDE was 286.0 ng g-1 dw (range – 81.9-17600.0 ng g-1 dw). For metals, selenium was found in all samples, mercury in 7, and arsenic, cadmium, and lead were not detected. Geometric mean concentrations of mercury and selenium were 0.1 and 1.2 µg g-1 dw, respectively. Concentration levels of OCs and metals were below levels known to affect productivity in birds, excluding one egg with an elevated p,p'-DDE concentration. No trends in depuration rates during the breeding season were found.

Predicting Heartwood Decay in Apparently Sound Western Larch for Snag Retention and Management

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Since many cavity-excavating birds require heart rot, managers routinely emphasize decayed trees in their snag retention prescriptions. Where too few trees are present with obvious indicators of decay, apparently sound trees are left to meet retention objectives. These trees may also contain decay, and may offer advantages in longevity and protection over more extensively decayed trees. Better information regarding conditions and heartwood decay-causing fungi important to heart rot in apparently sound trees would aid in retention decisions. We combined data from the 2003 Westside Reservoir and Roberts Fire burns with data from the USDA Forest Service Forest Health Protection's 10-year western larch (*Larix occidentalis*) merchantability study on the 2001 Moose Fire burn, all collected on the Flathead National Forest. We used dissection data from 284 apparently defect-free fire-killed western larch to predict the probability of heart rot related to tree age, diameter at breast height (dbh), elevation, aspect, habitat type, and heartwood-to-sapwood ratio. Fungi were isolated from trees with heart rot and identified through DNA analysis. We isolated *Stereum sanguinolentum, Echinodontium tinctorium, Sistotrema brinkmannii, Antrodia serialis, Phellinus chrysoloma*, and *Fomitopsis cajanderi* from trees in the three burn areas. All variables tested were significantly associated with probability of heart rot ($\mu = 0.05$), with age and dbh showing the highest predictive power through CART analysis. These preliminary findings support tree diameter as a critical characteristic in retaining trees most useable to wildlife, as well as retaining heart rot-causing fungi, which have undergone marked declines in other parts of the world.

Fish and Herpetofauna in the Powder and Tongue River Basin in Relation to Coalbed Natural Gas Development

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The Powder River Basin in Wyoming and Montana is currently undergoing one of the world's largest coalbed natural gas (CBNG) developments. Potential exists for substantial effects on riparian and aquatic ecosystems because CBNG development involves production and disposal of large quantities of coalbed ground water that differs from surface waters. We evaluated whether development affects fish and herpetofauna in the Powder River Basin in Montana and Wyoming. The purpose of the study was to determine if fish, amphibians, and reptiles were different in riparian areas of streams with and without CBNG development. We sampled 20 sites on eight streams in areas with development and 20 sites on eight streams in areas without development. Streams without development were deeper (*t*-test; $P = 0.04$), but the mean depth was only 8.4 cm deeper, which may not affect fish, amphibians and reptiles. Several fish metrics and an index of biotic integrity were used to compare fish assemblages in relation to the status of development within a drainage area. Streams in drainages with CBNG development on average had lower species richness than those without development. There were no significant differences between sites with and without

CBNG development in herpetofauna present (species richness, number of individuals, number of northern leopard frogs).

Sage Grouse Winter Habitat Selection and Energy Development

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The recent surge in energy development has resulted in rapid and large-scale changes to western sage-steppe ecosystems without a complete understanding of its potential impacts to wildlife populations. As part of a larger study investigating the impacts of coal-bed natural gas (CBNG) development on greater sage grouse (*Centrocercus urophasianus*), we modeled female winter habitat use in the Powder River Basin (PRB) of Wyoming and Montana to 1) identify landscape features that influence sage-grouse habitat selection, 2) assess the appropriate scales at which selection occurs, 3) spatially depict winter habitat quality in a geographic information system to aid in conservation planning and 4) assess the effect of CBNG development on winter habitat selection. Our findings highlight the need for landscape scale research to gain further insight into sage-grouse ecology. The strength of habitat selection between sage grouse and sagebrush was strongest at a 1000-m scale showing that the abundance of sagebrush over a landscape scale is an important predictor of use by sage grouse in winter. We generated a new index of topography "roughness index" which drastically out-competed all other topographic variables (wi ~1). Sage grouse avoided coniferous habitats and rugged landscapes at a 400-m scale. Our winter habitat model based on vegetation and topographic was validated by an independent data set of sage grouse winter locations (R^2 = 0.95). After controlling for vegetation and topography, the addition of a variable quantifying the extent of CBNG development within 1 km indicated that sage grouse in otherwise suitable winter habitat avoid CBNG development. This demonstrates that current strategies to mitigate impacts of CBNG on wintering sage grouse populations are insufficient. Our spatially explicit habitat prioritization tools, when coupled with knowledge of bird movements and active lek locations provide a biological basis for decision-makers to formulate an effective conservation strategy for sage grouse in areas undergoing energy development.

Bat Mortality at Wind Farms: a Summary of Recent Research Findings, and Management Implications for Montana Wind Power Development

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Bat fatalities at wind turbines have been documented worldwide, including North America. Annual mortality has been estimated to vary from < 2 to ~ 50 bats/turbine yr. Hoary, red, and silver-haired bats appear to have the highest frequency of mortality. All three species are migratory forest bats, even though mortality of these species has been observed at wind turbines located in grassland habitats. Bats seem to be most vulnerable to collisions with turbines during fall migration periods. Bats are long-lived species that have low reproductive rates, and low levels of mortality could have potentially high impacts on local populations. Pre-construction bat survey protocols for evaluating potential wind energy sites will be described, including a review of current research efforts to evaluate the effectiveness of

pre-construction bat detector surveys for predicting bat fatalities. Post-construction wind farm monitoring protocols for documentation of bat mortality will also be reviewed. Effective bat mortality monitoring may require more frequent monitoring intervals than those often used for bird mortality. This presentation also summarized on-going research efforts by Bat Conservation International and others on potential mitigation measures and deterrents for bats at wind farms. A list of web resources will be provided for those who wish to stay informed about the latest information related to wind energy and bats.

Aerial Inventory Methods for Greater Sage Grouse

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Concern has been expressed over the status and well being of sage grouse (*Centrocercus urophasianus*) populations throughout their range; including southeastern Montana. The potential for large scale energy extraction and development across much of sage grouse range and its effect on sage grouse habitats and populations increases this concern. An accurate inventory of population resources and where these resources exist is critical to assessing population status. Successful mitigation of development impacts cannot occur without a comprehensive population inventory. Prior to 1999 there had been no systematic inventory of sage grouse populations in Southeastern Montana FWP Region 7. Sage grouse population monitoring consisted of annually surveying sage grouse lek activity on four trend areas and opportunistically monitoring incidental "known" leks and noting "new" lek locations. Sage grouse winter area monitoring consisted of noting areas of concentration along seasonally accessible roads. Until 1999 364 lek locations were identified within the 18,000 mi^2 of potential sage grouse habitat in southeastern Montana. Beginning in 1999 systematic inventories for sage grouse were initiated. The region made a priority of locating leks and winter areas in unsurveyed habitat across the region. Aerial survey methods were deemed the most appropriate and efficient approach towards this end. In the past 8 years 90 percent (16,000 mi^2) of the potential sage grouse habitat has been aerially surveyed and the number of known lek locations has increased to 827. Presentation centered on techniques and use of aerial survey for sage grouse population inventory and monitoring.

Pre-Construction Evaluation of Proposed Wind Power Developments

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Montana has a rich wind resource which could be potentially developed if transmission capability issues are resolved. Wind energy is promoted as a 'green alternative' to traditional sources such as fossil fuels and hydro. However, there is potential for impacts to locally breeding and migrating birds through collisions with turbines, and increased fragmentation of habitat. Pursuant to USDI Fish and Wildlife Service guidelines, a pre-development site evaluation should be conducted at all potential wind sites, to determine if wind power development is likely to cause avian (bird or bat) impacts at levels of concern. Working with agency,

academic and industry personnel, we have developed a Potential Impact Index (PII) to evaluate sites proposed for wind power development. The index incorporates physical attributes, species occurrence, and ecological characteristics to assess the potential for wildlife impacts by wind power development before construction. This presentation will include a discussion of the potential impacts of wind power development on birds, explanation of the PII, and its application to pre-construction studies in Montana.

Partitioning Human Impacts on Riparian Bird Distribution along the Madison and Missouri Rivers, Montana

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Conservationists, managers, and land planners are faced with a formidable task of needing to balance many issues regarding the impacts of humans on natural systems. While numerous investigations have documented a variety of impacts, from over-grazing to housing development, we know little about the independent effects of human impacts on biodiversity. This is unfortunate because managers and conservationists need such information to guide difficult decisions regarding where to allocate limited resources. Riparian forest habitats in Montana illustrate this problem, where many potential stressors can affect wildlife. We estimated the relative effect of anthropogenic stressors on birds using 105 riparian forest patches across three regions along the Madison and Missouri Rivers, Montana. We partitioned the effects of grazing, invasive plant species, habitat loss and fragmentation, and development and discuss the independent effects of each potential stressor on avian species richness and the occurrence of 35 bird species. For instance, grazing intensity, invasive plant cover, and under-story vegetation were all correlated, with high grazing intensity being positively correlated with invasive species cover, both of which were negatively correlated with the amount of under-story vegetation. Much of the effects on bird distribution can be explained by nesting and foraging substrates of these species. We end by providing recommendations on riparian forest management for Montana.

Evaluating Habitat Restoration Using Bird Communities: a Spatially Explicit Approach and Application to Aquatic Systems

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Habitat restoration is one of the only alternatives for conserving biodiversity in threatened landscapes. Biologists and managers are not only faced with restoring habitat, but also with the critically important task of evaluating the potentially widespread effects of restoration. Determining the success of restoration can be complex, however, because management can have a variety of effects on plant and animal communities. Here we describe the merits of using information on bird communities collected at landscape scales to evaluate restoration success. We illustrate this approach with an example from ongoing restoration at Odell Creek, a small stream located near the Madison River, Montana. We identify the following advantages to using bird communities for evaluating restoration success: 1) systematic data can be collected easily and less expensively than for other vertebrates, because birds are the most

visible and active vertebrates; 2) information can be rapidly gathered for dozens of species across broad spatial scales; 3) collective effects of restoration can be integrated into information on bird communities, such as effects on water quality, insect abundance, vegetation, or microclimate; and 4) the identification of effective indicators is highly probable because birds vary widely in their requirements and life history strategies. Furthermore, sampling designs that allow assessment of the spatial extent and magnitude of restoration effects can easily be implemented. Our approach should help act as a springboard for initiating future restoration on private lands, improving methods of restoration, and using existing data to predict restoration potential.

Influence of Post-fire Timber Harvest on Black-Backed Woodpecker Nest Survival and Nest Site Selection

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Post-fire timber harvest practices, i.e. post-fire salvage logging, on public lands are a highly contentious issue in the western United States. Harvest of burned trees impacts a number of species, particularly those specialized for using post-wildfire habitats. We assessed the effects of post-fire salvage logging on black-backed woodpecker (Picoides arcticus) nest survival and distribution within burned, mixed conifer forests of south-central Oregon. Multiple treatment and control plots were surveyed two years pre-logging (2003-2004) and two years post-logging (2005-2006). A total of 212 black-backed woodpecker nests were monitored during the four year post-fire period, with nest densities peaking in year three. Nest survival models containing temporal predictors (i.e. Julian date) performed better than those related to salvage harvest or other habitat features. Similar to previous studies, our results indicate that black-backed woodpeckers exhibit high overall nest survival (76.8%; range 67.9-83.6%) and select nest sites with higher snag densities than non-nest random sites. Nest survival and density appeared unaffected by salvage logging, contrary to our predictions. Upon completion, this project will supply agencies and managers with scientific data regarding post-fire habitat conservation for a sensitive woodpecker species.

Conserving the Plains Bison: an Unfinished Conservation Legacy

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Within the span of a few decades during the mid- to late-1800s bison (*Bison bison*) were reduced by hunting and other factors to a few hundred individuals. The plight of the plains bison led to one of the first major movements in orth America to save an endangered species. Attempts to hybridize cattle and bison when bison numbers were low resulted in extensive cattle gene introgression in bison. Today, though approximately 00,000 plains bison exist in North America, few herds are free of cattle gene introgression. Small herd size, artificial selection, cattle-gene introgression, and other factors threaten the diver ity and integrity of the bison genome. In addition, the bison is for all practical purposes ecologically extinct across its former range including Montana, with multiple consequences for grassland biodiversity. Urgent measures are needed to conserve the wild bison genome and to restore the ecological role of bison in grassland ecosystems. Socioeconomic trends in the Great Plains, combined with new information about bison conservation needs and new conservation initiatives by both the public and public sectors, have set the stage for significant progress in bison conservation over the next few years. We outline some of these new initiatives focusing on specific opportunities in Montana.

The Use of Fecal DNA to Describe the Genetic Population Structure of the Greater Yellowstone Area Bison with MTDNA

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Bison (*Bison bison*) populations of Yellowstone National Park (YNP) and Grand Teton National Park (GTNP) are the last remaining representatives of their wild, free ranging ancestors. Knowledge regarding population structure is crucial to their conservation, and may have important implications for understanding their ecology and evolution. Prior microsatellite studies of YNP bison captured outside of the park suggested the possibility of three subpopulations. An expanded assessment of population structure and gene flow between GYA bison populations through non-invasive fecal sampling, and the addition of mtDNA sequencing could provide further insight. Non-invasive fecal sampling has been used, with a high degree of success, in genetic studies of other ungulates. However, DNA amplification from fecal samples can be challenging and result in high genotyping error rates. Variation in fecal DNA quality and quantity, PCR amplification rates, and genotyping error rates from fecal samples has not been assessed in bison. We evaluated the feasibility of fecal DNA sampling for genetic analysis of wild bison populations. Variation in fecal mtDNA quality and quantity, PCR amplification rates, and sequencing error for bison fecal samples was evaluated. Sequencing of the bison mtDNA control region was used to evaluate haplotype diversity, population structure between breeding groups among YNP, and between GTNP and YNP bison populations. We found differentiation among breeding groups and a unique haplotype. Female philopatry may play a significant role in population structure and gene flow in naturally regulated, free ranging wild bison populations. Future studies using microsatellites could provide further insight.

Elk Behavioral Responses to Re-establishment of Wolves: the Indirect Consequences of Living in a Risky Environment

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It is well-documented that predators limit prey populations in many systems through the direct killing and consumption of prey. What is less well studied and understood are the indirect consequences of predators on the behavior of prey that are attempting to minimize predation risk. We conducted an intensive telemetry-based study of the Madison-Firehole elk (*Cervus elaphus*) herd and colonizing wolves (*Canis lupus*) in the central portion of Yellowstone National Park from 1991-2006 to test the prediction that wolves have altered various

elk behavioral responses including group size, winter home range size, activity pattern , and habitat selection. Prior to significant wolf reestablishment of the tudy area (1991-1997), we randomly collected approximately 6000 elk locations, representing 5000 elk group with associated group size, activity budgets, and habitat selection attributes These data are complimented by more than 5000 elk locations, representing 3500 elk groups and associated data when wolves had an established presence in the study system from 1998 through 2006 After wolf re-introduction elk that formally lived in a predator-free environment for many decades were subjected to varying levels of predation risk thus allowing us to investigate how these behaviors change at different temporal and spatial scales. Comparison of pre-wolf and post-wolf data demonstrates changes in elk behavior at a variety of spatial and temporal scales; presumably due to elk responses to predation risk. It is unclear whether these behavioral changes resulted in decreased individual fitness or reductions in population vital rates; however, we hope that continued monitoring will provide additional insights as this predator-prey system develops.

Effectors of Elk Summer Home-Range Size, Movement and Timing of Fall Migration

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For decades, research has emphasized the effects of roads, trails, and human use of the landscape on wildlife habitat availability and use. Historically, studies have assessed the impacts of human perturbations on the landscape by analyzing relatively infrequent VHF radio-tracking data or by track and fecal surveys. The deployment of 49 GPS radio-collars on adult, female elk (*Cervus elaphus*) in the Madison Valley, Montana during the winters of 2004-2005 and 2005-2006 provided opportunity to look at elk movement on 30-min intervals over the period of an entire year. Using the high-frequency of locations provided by these collars, we estimated the effects of roads and trails on elk summer home-range size, movement on 30-min intervals throughout the year, and factors influencing the timing of elk departure from their summer home-ranges and migration to winter ranges in the Madison Valley. Preliminary results from the first year of data suggest that various levels of human access influence elk movement differently at varying periods throughout the year, that there are regional differences in these effects, and that movement levels may not be a good indicator of home-range size. Varying levels of road and trail access during the hunting seasons appear to influence timing of elk departure from summer home-ranges, in combination with snow levels and regional differences. Collection of the second year of collars in February, 2007 will provide substantially more data and should help elucidate our understanding of influences on elk movement and behavior on a year-long scale.

Wildlife Meets Energy Boom

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The Upper Green River Basin is experiencing an energy boom beyond all expectations. The Pinedale Anticline and Jonah fields are considered among the top five gas producing fields in the U.S. Our nation's voracious appetite for natural gas leaves Upper Green River Basin area managers with the task of balancing world-class wildlife populations with developing world-class gas fields. Environmental impact analysis is challenged to keep up with rapid advances in technology and complex wildlife issues. Industry is currently proposing development on the Anticline beyond 2025, based on today's technology and estimated recoverable gas reserves. The effect of energy development on wildlife has already been significant. Wyoming Game and Fish Department has been working collaboratively with industry and surface managing agencies to address the issues. This presentation will reveal that there are no easy choices and most obstacles are formidable.

Conservation Planning along Montana's Front Range: Are We Conserving the Right Ecosystem Conditions?

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Conservation planning has at least two important levels that should be addressed if conservation objectives are to be met. The first level is ensuring that lands remain in uses capable of meeting the conservation objectives through purchases, easements, or other protection tools. The second level addresses if the existing conditions are appropriate to support the conservation objectives, and if not, what changes are needed. Montana's Front Range is recognized for its high conservation value and has seen considerable effort to protect these lands from development through easements. EMRI has been working with cooperating ranchers to assess the existing ecosystem conditions in a delineated planning area along the Front Range, and to compare these conditions to an historical reference. We developed a description of historical grass/shrub and riparian/wetland ecosystems in the area. We have conducted field sampling of vegetation for the past two summers to compare to the historical reference. The Front Range supports a very high diversity of plant species and is a critical area for many wildlife species. Preliminary results reveal that non-agricultural grass and shrub ecosystems are in good condition at the ecosystem level, but the riparian ecosystems have very high levels of exotic species. Management that returns fire to the grassland ecosystems and that reduces the levels of exotics in riparian areas is recommended.

Wolf and Elk Predator-Prey Dynamics i Banff National Park Alberta

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Wolves recolonized Banff ational Park (B P) in the early 1980s, and quickly regained their role as top carnivore for the primary prey species, elk. Research has established that wolf predation is an important limiting factor for elk and moose, and was correlated with significant elk population declines. Effects of wolf predation were also detected on other ecosystem components in a fashion consistent with a top-down trophic cascade. However, whether wolves can regulate elk to low density has not been addressed. I used wolf kill rates of elk, wolf and elk densities measured during winter from 1985-2005 to test whether wolf predation regulated elk to low densities. I fit simple prey dependent and ratio-dependent models to time series data to estimate the functional response of wolves to changes in elk den ity. I used linear and non-linear models to estimate the numeric response of wolves to chan es in elk density. Model selection methods were used to select the best functional and numeric response models for wolves and elk. I then combined functional and numeric responses to estimate wolf predation rate as a function of elk density to identify dynamic equilibrium states. Evidence suggests wolves can regulate elk to low densities in this multiple-prey system where predator prey dynamics were largely driven by type II prey-dependent functional response and a Y-intercept in the numeric response. I compared kill-rates from Yellowstone ational Park and other areas to model predictions, and discuss the generality of these results across wolf-elk systems.

Postcards from the Edge: A Snapshot of the Effect of Oil and Gas Development on Large Mammals in Alberta's Forests

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Energy development is the primary policy directive in Alberta, and as a re ult, oil and gas impacts a variety of wildlife species. We provide a brief scientific review of the effects of oil and gas development on large mammal species in forest ecosystems in Alberta. Oil and gas development can impact wildlife directly, for example through increased mortality or direct habitat loss, or indirect, mediated by changes in other pecies uch as predators. Woodland caribou in Alberta are declining and three populations are at risk of immediate extirpation. Caribou suffer from direct loss of old growth forest from pipeline, road, seismic line and well site clearings, direct disturbance from seismic blasting, and increased poaching and highway

mortality because of increased access. Caribou also suffer indirect effects such as increased predator efficiency by wolves, which may increase predation rates. Grizzly bears suffer less from direct habitat loss, and can actually be attracted to increased forage production in disturbed areas. However, grizzly bears suffer the most from human caused mortality associated with increased human access. Elk are similar to grizzly bears, except they suffer the indirect effect of increased wolf efficiency with increasing development. Some species, such as white-tailed deer and coyotes, indicators of disturbed habitats, show signs of benefiting from oil and gas development, further altering ecosystem dynamics. Mitigation strategies for reducing negative effects of oil and gas are presented. However, a case study of the failure of the policy process in Alberta to mitigate these effects for caribou is presented, and recommendations for Montana were discussed.

Effects of Coalbed Natural Gas Development on Herpetofauna in the Powder River Basin

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Coalbed natural gas (CBNG) development is expanding worldwide, yet the full ecological impacts are unknown. Changes in water quality and surface disturbance associated with CBNG development have potential to alter the herpetofauna present. We evaluated whether development affects herpetofauna in the Powder River Basin in Montana and Wyoming. The purpose of the study was to determine if herpetofauna was different in riparian areas of streams with and without CBNG development. We sampled 20 sites on eight streams in areas with development and 20 sites on eight streams in areas without development. Streams without development were deeper (t-test; $P = 0.04$), but the mean depth was only 8.4 cm deeper, which may not affect amphibians and reptiles. There were no significant differences between sites with and without CBNG development in water quality (stream conductivity, dissolved oxygen, water temperature, pH) or herpetofauna present (species richness, number of individuals, number of northern leopard frogs).

Success of Grizzly Bear Population Augme tation in Northwest Montana

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The Cabinet-Yaak grizzly bear recovery zone is located in northwest Montana and northern Idaho. The population has been estimated to be 30-40 grizzly bears. The Cabinet Mountains portion of this area may be isolated from the remainder of the zone and was the site of a test of grizzly bear population augmentation. Between 1990 and 1994, four sub-adult females (2-6 yrs old) were translocated from the Canadian Rocky Mountains of southeast

British olumbia into the Cabinet Mountains. one of the animals involved had any history of conflicts with humans. The objectives of that experiment were to evaluate site fidelity, reproduction, and long-term survival of the translocated bears. Three of the four transplanted bears remained in the target area for 1 year or more and satisfied the short term goal for site fidelity. Recent genetic evidence gathered through hair snagging efforts have determined that at least one of the original transplanted animals remained in the Cabinet Mountains and has reproduced thereby providing evidence of success for the long term goals of survival and reproduction. This paper reports on the results of long-term monitoring of that experiment. We also report on our use of D A hair-grab sampling to track survival and reproductive fate of one translocated female.

Aspen Height, Stem-Girth and SUrvivorship in an Area of High Ungulate Use

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An increase in an ungulate population potentially exposes aspen suckers, saplings, and trees to an increased level of use. This study examined how stem height and stem girth influenced the selection of stems by ungulates for browsing, rubbing, and gnawing, and reconstructed the history of ungulate use for the study area. Transects were run through each of three aspen clones growing on the Fleecer Wildlife Management Area to determine the height, circumference, and surface area of stems injured by rubbing and gnawing. Stems in the height range of 20 to 250-cm tall were browsed. Stems 2- to 13-cm diameter and greater than 80-cm tall were preferentially selected for rubbing and gnawing. The area of exposed xylem on dead saplings was 2- to 3 times the area of exposed xylem on live stems. There were no live stems in the 76- to 349-cm height range. Based on an analysis of stem height and age, ungulate use of the aspen clones was inferred to have increased from a light-to-moderate level to an intense level in the early 1990s. We concluded that elk were primarily responsible. The findings of this study have implications for aspen restoration programs and wildlife management. Where ungulate numbers are high and aspen is desired, aspen should be protected from browsing, rubbing and gnawing until stems reach about 13-cm diameter and have grown out of the browse zone. In this study area, aspen would require about 25 yrs to grow to that size.

Montana Wetland and Riparian Mapping Center

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A new wetland and riparian mapping center has been established for Montana that will map to USDI Fish and Wildlife Service (USFW) standards using the ational Wetland Inventory (NWI) and the System for Mapping Riparian Areas in the Western United States classifications. Unlike most of the U.S., the WI was never completed in Montana and our equally important riparian areas also lack comprehensive mapping. All mapping follows USFWS quality control procedures and will be incorporated into the WI national geodatabase after final SFWS approval. Mapping data will then be available to the public through

the USFWS NWI and the Montana Natural Resource Information System (NRIS) websites. Mapping is delineated on year 2005 1-meter resolution color infrared aerial imagery. Field verification follows to increase accuracy in problematic areas and to gather data about specific sites of high ecological significance (this data is entered into our Natural Heritage database). A guide to the vegetation, ecological functions, and management considerations of NWI types is located at our www.mtnhp.org website with additional information to be added as mapping continues. The mapping is dependent on partner funding and is ongoing in several areas of Montana with efforts to secure more funding underway. Contact Greg Kudray at gkudray@mt.gov or 444-0915 for additional information.

At-Scale Adaptive Management in Recovery Efforts for Piping Plovers on Alkali Lakes in North Dakota and Montana

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Recovery of threatened and endangered species requires managers to implement adaptive management at scales sufficient to reverse declines. The Great Plains population of piping plover was listed federally as a threatened species in 1985. Despite listing, the population continued to decline across the entire Great Plains until 1998 when the USDI Fish and Wildlife Service and the Conservancy, in cooperation with state game agencies and private landowners, implemented a collaborative management and monitoring approach. This effort, in combination with research on improving reproductive success and habitat quality, has resulted in population growth in 6 of the past 8 years for alkali lake-associated birds. Management to date has dealt primarily with addressing the primarily stress, altered predator communities. In 2005, we launched management that is designed to address the source of the stress by eliminating artificial predator habitat and restoring fragmented landscapes favorable to mesocarnivores. We also broadened the partnership for these efforts, gaining the financial support and focus of the Natural Resources Conservation Service. Results of this effort represent implementation of adaptive management at-scale through a multi-partner approach.

Does ENzootic Plague Affect Black-Footed Ferret Survival?

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Black-footed ferrets (*Mustela nigripes*) were first reintroduced in Montana in 1994 on the UL Bend National Wildlife Refuge and later on the Fort Belknap Indian Reservation and on Bureau of Land Management lands in Phillips County. More than 500 ferrets have been released and over 250 wild-born kits have been observed. Sixteen ferrets were known alive in Montana in October, 2006. Fundamentally, small and fragmented complexes of black-tailed prairie dog (*Cynomys ludovicianus*) colonies provide limited habitat. Sylvatic plague, caused by the bacteria Yersina pestis and vectored by fleas, can cause significant mortality in both prairie dogs and ferrets. The effects of epizootic plague are often dramatic with near 100 percent prairie dog mortality across hundreds of acres within weeks, eliminating both prey and habitat for ferrets. We hypothesized that enzootic plague, i.e. low, background levels of the disease, may also affect ferret survival. We conducted a manipulative, experimental investigation utilizing Deltamethrin dust to reduce flea populations and an experimental plague vaccine in ferrets. Survival of released ferrets and resident wild-born animals was monitored on comparable dusted and non-dusted prairie dog colonies. Half of all resident ferrets and half of all released animals were vaccinated against plague. Results from logistic regression analysis of data from 137 ferrets, spanning 222 survival intervals, provided the first direct evidence that enzootic plague decreases ferret survival. Plague and maintenance of sufficient habitat continue to present significant challenges for recovery of endangered black-footed ferrets.

Aspen Restoration by Beaver oN Yellowstone's Northern Range

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Aspen (*Populus tremuloides*) on the Gardiner Ranger District of the Gallatin ational Forest have declined in recent years. In 1991 beaver were reintroduced into Eagle Creek to stimulate aspen suckering and create more riparian areas. In 2005 a study was initiated to test the hypothesis that beaver increased aspen density and recruitment. We compared active beaver sites (n = 6), sites abandoned for 1-3 years (n = 7), sites abandoned for 4-6 years (n = 4), sites abandoned for 7-11 years (n = 5) and control sites which had less then 10 percent beaver utilization (n = 5). Thirty1-m2 plots were used to determine aspen density and one 60-m2

belt transect was used to calculate size class distributions at each site. Comparisons between sites were made using ANOVA for unequal sample sizes. Aspen densities in active sites and sites abandoned for 1-3 years were similar (2.6/m^2) and increased ($P = 0.01$) compared to all other sites (1/m^2). New sprouts and saplings were greater ($P = 0.01$) on active sites and sites abandoned 1-3 yrs compared to all other sites. Sites abandoned by beaver from 4-11 yrs failed to increase aspen recruitment. We concluded that beaver activity stimulated aspen growth, but ungulate herbivory prevented aspen regeneration in Eagle Creek.

Snowshoe Hare Abundance, Distribution, and Habitat Use in Glacier National Park

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Glacier National Park supports a population of the federally Threatened Canada lynx (*Lynx canadensis*), but little is currently known about their principal prey in Glacier, snowshoe hares (*Lepus americanus*), that makes it difficult to assess which habitats in the Park may be suitable for lynx. In summer 2005 we implemented a 3-yr study on snowshoe hare abundance, distribution, and habitat use in Glacier with a secondary objective of developing a non-invasive genetic sampling approach that could be of general benefit to National Parks initiating monitoring programs. Our data to-date suggested that snowshoe hare populations are patchily distributed throughout Glacier National Park. There was little or no evidence of hares in >60 percent of the forested sites we surveyed. The highest hare densities we recorded in the Park occurred near the Two Medicine area in the Park's southeast corner, and in the post-burn regeneration from the 1988 Red Bench fire in the Park's northwest corner. Snowshoe hare use of post-fire regeneration from the 1988 burns is highly variable. Although our two highest hare density sites occurred in these burns, half of our study sites in the 1988 burns had little or no evidence of snowshoe hares. A non-invasive genetic sampling approach shows potential for providing reliable hare density estimates in difficult-to-access areas of relatively high hare densities (>1 hare/ha). However, at the lower hare densities found throughout much of Glacier National Park, our current non-invasive sampling methods do not yield sufficient pellets for reliable mark-recapture density estimation.

Influence of Pack Size, Demography, And Human Caused Mortality on Breeding Pair of Wolves in the northern Rocky Mountains

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The breeding pair is the reproductive unit within a wolf (*Canis lupus*) population, and is the legal and biological benchmark for wolf management. Management of the recovered wolf population in the northern Rocky Mountains (NRM) requires monitoring breeding pairs. Because pack sizes are easier to monitor than breeding pairs, we estimated the probability a pack would contain a breeding pair based on its size for wolf populations inhabiting six areas in the NRM. We also evaluated the extent to which differences in demography of wolves and levels of human-caused mortality among the areas influenced the probability packs of different sizes would contain a breeding pair. Probability curves differed among the analysis areas, depending primarily on levels of human-caused mortality and secondarily on population growth rate; population size and recent changes in population growth had little effect. Breeding pair probabilities were more uniformly distributed across pack sizes in areas with low levels of human mortality and stable populations. Probabilities were skewed towards large pack size in areas with high levels of human-caused mortality and high growth rates; small packs had little reproductive success. Our approach can be used by managers to estimate the number of breeding pairs in a population where number of packs and their sizes are known. Following delisiting of NRM wolves, human-caused mortality could increase, resulting in more small packs with low probability of breeding success; monitoring of breeding pairs will provide more accurate insights into population dynamics of wolves than will monitoring number of packs or individuals.

BLM's Development of an Approach to Monitoring Regional-Scale Impacts of Energy Development on Wildlife

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The USDI Bureau of Land Management's (BLM) monitoring related to wildlife and energy development is generally focused on compliance and effectiveness monitoring at the local lease level. This focus brings efficiency and direction to local energy programs, but does not allow monitoring of species and habitats at larger scales. Because many species have habitat requirements or ranges well beyond localities where energy development occurs, analysis of monitoring information should occur on a corresponding scale. BLM's regional-scale monitoring activities must involve shared information and application over multiple planning areas, Field Offices or State Offices. Regional information alone will not be sufficient to determine effectiveness of local mitigation measures, improve cumulative impact analysis, or track landscape changes over time. However, a comprehensive regional approach that incorporates local monitoring information can improve understanding of the circumstances under which land-use changes influence health and condition of expansive or dispersed habitats and wide-ranging species. The BLM is developing a process to monitor regional effects of energy (primarily oil and gas) exploration and development on wildlife species and habitats. BLM has contracted development of two regional monitoring approaches—in northwest Colorado and on Alaska's North Slope; each will be independently developed from a common theoretical framework. After completion of the contracted products, BLM will select the strongest elements to assemble and implement a single national program for regional wildlife monitoring. This regional approach could also be utilized in addressing cumulative impacts and species conservation planning in support of decision-making in land use planning, NEPA documentation, and ESA compliance.

West Nile Virus and Greater Sage Grouse

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West Nile virus (WNv) has emerged as a new issue in conservation of native avifauna in orth America. Mortalities from WNv decreased survival of female greater sage grouse (*Centrocercus urophasianus*) by 25 percent across four populations in Wyoming and Montana, USA, and Alberta, Canada. Findings are troubling because survival of adult females is a limiting factor in population growth, and losses from WNv come at a time of year when survival typically is high. An outbreak of WNv in 2003 resulted in the local extirpation of a ~130-km^2 area in the Powder River Basin (PRB) in northeast Wyoming. In 2004 W v spread to populations in Colorado and California, and female survival was 10 percent lower (86%) at four sites with confirmed WNv mortalities than at eight sites without. Mortality from W v was ~2 percent in 2005 in the PRB in Montana and Wyoming, and decreased prevalence of infection and mortality in sage grouse, humans, and horses left many wondering if the worst had passed. Unfortunately, mortality from WNv increased again in 2006 in the PRB as hot temperatures returned, and three more states reported mortality for the first time (Oregon, Idaho and Nevada). In separate trials at the Wyoming State Veterinary Laboratory, all sage grouse

($n = 44$) experimentally infected with WNv died in 6-8 days regardless of dosage, thus confirming extreme susceptibility to this disease. In 2003 and 2004 in the PRB, all live-captured birds tested seronegative for neutralizing antibodies to WNv. In spring 2005 and spring 2006, 10.3 and 1.8 percent, respectively, of newly-captured females tested seropositive and represented the first documented cases of sage grouse surviving infection with WNv. However, a consistent pattern of low WNv-related mortality in summer followed by low seroprevalence the following spring in all years suggests that, to date, only ~14 percent of sage grouse in the PRB have been infected. Naturally low infection rates and survival of sage grouse following WNv suggested that most sage grouse in the PRB have not yet been exposed to the virus and remain susceptible. For sage grouse, severity of future WNv epizootics in the PRB will likely depend more on temperature and changes in vector distribution than on resistance to disease. Until we better understand epizootiology of WNv in sage grouse habitat, we suggest that management to reduce its impacts focus on eliminating man-made water sources that support breeding mosquitoes known to vector the virus.

Impacts of Oil Exploration and Production to Waterfowl Production Areas Managed by the USDI Fish and Wildlife Services Northeast Montana Wetland Management District (WMD)

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Jon C. Reiten, Montana Bureau of Mines and Geology, Billings, MT

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The Northeast Montana Wetland Management District (WMD), manages 44 Waterfowl Production Areas (WPA). Mineral estates were reserved when these parcels were purchased resulting in numerous oil wells on WPAs (several WPAs have wells located ≤ one half mi of a WPA wetland). These WPAs are located in the continuation of the prairie pothole region of the Dakotas, as well as the Williston Oil Basin, which is Montana's top oil producing area. The dominant waste product from the oil production process is produced water, and this basin contains some of the most saline water in the United States, often > 300,000 µs/cm specific conductance. Disposal of drilling wastes and produced waters occurred in unlined reserve pits until the late 1970s when liners were required. Based on average pit size and conservative chloride concentrations, an estimated 260 tons of sodium chloride salts are present in each pit. This research was conducted to address concerns over migration of salts from reserve pits into wetlands on WPAs. Produced water impacts were documented in half of 80 wetlands sampled on 23 WPAs. Saltwater plumes migrating out of reserve pits were delineated using an EM-31 soil conductivity meter and a Trimble GeoXT and mapped using ArcGis. Monitoring wells installed within the mapped plumes to determine water quality revealed that sodium chloride brines and to a lesser extent, trace elements and hydrocarbons had migrated out of the reserve pits. Further, some of these constituents migrated to nearby wetlands.

Habitat and Subdivision Growth Models for Predicting Past and Future Habitat Loss from Rural Subdivision Development

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Rural subdivision development is perhaps the greatest current threat to wildlife habitat in MT and throughout the west. In order to plan for these changes, it is important to identify existing significant habitat, determine where subdivision development will most likely occur, and determine how future development will reduce living habitat and connectivity for wildlife. Using Gallatin County, Montana, as an example, I used a suite of focal species models to categorize current wildlife habitat and coupled the output with a subdivision growth model developed by the Sonoran Institute to estimate changes from 1975 to current and to predict future losses from now until 2015 and 2025. The strength of the habitat models I developed for grizzly bears, elk, and antelope lies in their use as focal species to identify specific habitat assemblages and the scale of output. They are sensitive to placements of roads and structures and can predict how different configurations within subdivisions can influence habitat quality and permeability. This ability has been enhanced by vegetation classification of color orthophotos to produce more accurate and finer-scaled model output. Predictive changes using the growth model are at a quarter-section scale, summing up cumulative change and trends over larger areas. Tools such as these may be helpful for guiding the amount, specific configuration, and placement of growth, thus maintaining important areas and reducing wildlife-human conflicts.

Relationships among Moose Abundance, 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 moose 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 landbirds 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 summer of 2006. Measurements indicate current levels of moose 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. Of these species, only White-crowned Sparrow and Yellow Warbler demonstrated habitat selection based on willow vegetation characteristics

quantified. Common Yellowthroat, Lincoln's Sparrow, and Song Sparrow were best predicted by habitat type. Thus, consideration of other habitat characteristics such as herbaceous cover and bare ground should be considered in future management objectives. Additional vegetation sampling in conjunction with improved monitoring of moose populations utilizing the Refuge will allow managers to make informed decisions concerning moose harvest limits and conservation of willow communities.

Idiot Wind: the Wisdom of Bob Dylan[1]

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Former Congressman Pat Williams told us at last year's Montana Chapter meeting that we—wildlife biologists in Montana—have won. As evidence, he stated that logging on public lands is down, that grazing isn't the issue it once was, and that economic growth in Montana is greatest near public lands and wilderness. I suggest and provide evidence that this could just as easily be evidence that we've lost—or at least are losing. In addition, global warming, resource shortages, oil and gas development, subdivision, human population growth, a volatile political climate, and lax zoning regulations challenge us today and will vex future generations of wildlife biologists. The North American Model of Wildlife Conservation is an excellent history of how we achieved success in the past and sometimes achieve success today but will be woefully inadequate, by itself, to address these and other emerging issues. New alliances with those sometimes viewed as traditional foes and first-time battles with those sometimes viewed as traditional allies will be necessary in the fight to save wild areas and wild things.

[1]"What's good is bad, what's bad is good, you'll find out when you reach the top. You're on the bottom." – Bob Dylan

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The Effects of Highways on Elk Habitat in the Western United States and Proposed Mitigation Strategies

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Ken Wall and Robin Wall, Geodata Services, Inc., 104 South Ave. E., Missoula, MT 59801

The project's purpose was to assess the effects of highways in the Western United States on elk (*Cervus elaphus*) and elk habitat. Elk are an important wildlife resource in the Western United States and have significant social and economic values. Elk also are a focal species for most western state wildlife agencies and land management agencies. The authors quantified the existing direct and indirect effects pf highways on elk habitat on a state-by-state basis and propose mitigation measures based on the impacts. The results will have widespread implications to state wildlife agencies, land management agencies, transportation agencies, conservation groups and the general population that is concerned about elk conservation. The authors also quantified elk mortality on highways and provide recommendations to mitigate elk mortality, habitat loss and improve highway safety for motorists. The project was supported by the USDA Forest Service and Rocky Mountain Elk Foundation.

Climate Trends and Ecosystem Responses in Montana

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Although global warming trends are widely acknowledged around the world, substantial climate change is already occurring in Montana. The most obvious trend in Montana of the last 50 yrs is late winter warming and earlier spring snowmelt. This climate trend is generating longer growing seasons AND longer wildfire seasons. Impacts on Montana terrestrial and aquatic ecosystems are only now beginning to be noticed. This talk will summarize global, regional and Montana climate trends and some critical ecosystem responses now being detected, and speculate on where the biosphere will go from here.

The Role of the USDI Fish and Wildlife Service in Permitting Energy Development in Montana

Shawn Sartorius, Fish and Wildlife Biologist, USDI Fish and Wildlife Service, Billings, MT 59101

The National Energy Policy was codified in 2005 by the Energy Bill of that year. The goal of the legislation was to decrease U.S. dependence on foreign energy supplies by increasing U.S. production, efficiency, and use of alternative fuels. As part of the effort to increase domestic oil and gas production, an Energy Pilot Project was initiated to streamline oil and gas exploration and production permitting on Federally owned mineral estate. This project provided money to key BLM Field Offices in the West for staff that would be dedicated to permitting oil and gas projects in a timely manner. Money was also appropriated for personnel in supporting agencies with regulatory authority over oil and gas projects. The USDI Fish and Wildlife Service has added staff, often co-located in USDI Bureau of Land Management (BLM) Field Offices to coordinate endangered species consultation and other aspects of wildlife management required by statute. In Montana, there are numerous challenges facing wildlife and land managers in the Powder River Basin of southeastern Montana as they cope with increasing extraction of coal bed methane gas reserves. The USDI Fish and Wildlife Service continues to engage with all interested parties to find solutions to these complex challenges.

Evaluating Impacts of Natural Gas Development on Mule Deer in Western Wyoming

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Increased levels of natural gas exploration, development, and production across the Intermountain West have created a variety of concerns for wildlife populations and their habitats. In July of 2000, the USDI Bureau of Land Management approved development of 700 producing wells, 400 miles of access roads, and 276 mi of pipeline to develop gas reserves in the Pinedale Anticline Project Area (PAPA). The PAPA provides important winter habitat to 4000-5000 mule deer that summer in portions of four different mountain ranges of northwest Wyoming. We used a variety of data collected prior to and during gas development to examine the potential impacts of natural gas development on mule deer in the PAPA. We discuss results from the first 5 years of gas development, including 1) estimated acreage and sources

of direct habitat losses, 2) changes in mule deer habitat selection patterns and indirect habitat losses, and 3) population performance of mule deer in the PAPA. Through 5 yrs of gas development we documented: 1) > 1,300 acres of direct habitat losses to access roads and well pads, 2) changes in deer distribution, i.e., avoidance of gas wells, and 3) a 45-percent reduction in mule deer abundance. Our study uggests that habitat selection patterns and population performance of mule deer wintering in the PAPA have been affected by natural gas development. Mitigation measures designed to minimize impacts to wintering mule deer should consider development strategies that reduce direct habitat losses (e.g., directional drilling) and human activity, e.g., fluid collection systems. Further, reducing disturbance to wintering mule deer may require approaches that limit human activity during both production and development phases of wells.

Assessing Fisher Distribution and Connectivity in The U.S. Rocky Mountains Using Non-Invasive Genetic Sampling

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In 2004 the USDI Fish and Wildlife Service responded to a petition to list the West Coast Distinct Population Segment (DPS) of fishers under the ESA. They ruled that the West Coast DPS was "warranted, but precluded" by higher priorities. Fisher are apparently rare in the West Coast, yet they are common in the Northeastern and Midwestern portions of the United States; over 2000 fisher are legally trapped in Maine, ew York, and Minnesota each year. In the Rocky Mountains, the only other area of the United States that has fishers, there is little information regarding their distribution and population status. Idaho confers fisher its highest level of protection by listing the species as "critically imperiled" and a Species of Greatest Conservation Need under its Comprehensive Wildlife Conservation Strategy. Given recent management concern regarding fishers, multiple agencies, institutions, and organizations have recognized the need to obtain some basic information in the Rocky Mountains. Of primary interest is determining the geographic range of this species within the Rocky Mountains. Current available maps are either too general, e.g., brushstroke maps, and thus contain habitat that is not currently occupied by fisher, or are based on untested habitat relationships or unscreened sighting data. This talk will describe a large-scale, multi-institution effort currently underway to delineate the geographic range of fisher using non-invasive genetic sampling. In addition, preliminary genetic data on the population structure of fishers in the Rocky Mountains will be presented.

SUrvival Costs of Reproduction during the Hunting Season Greater Sage Grouse: a Case Study in Central Montana

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Direct investigation of how harvest affects population vital rates and population growth, and the magnitude of harvest effects relative to other sources of mortality, is needed for informed management of harvested species. Greater sage grouse (*Centrocercus urophasianus*) are a species of concern and are still legally harvested in most of their current range,

including Montana. Due to uncertainty about the impact of harvest on vital rates and about the relative importance of harvest compared to other sources of mortality for sage grouse, we implemented a case study to simultaneously compare survival rates between adjacent hunted and nonhunted sites and to evaluate nonhunting factors influencing survival during the hunting season. We monitored the reproductive activity, survival rates, and causes of mortality of females using radio-telemetry in central Montana during 2004 and 2005. We included year, within-season variation, site, female age, and the cost of reproduction as covariates in our survival analysis. Female survival during the hunting season was lower for females with greater reproductive investment, and females on the hunted site had lower survival than females on the nonhunted site. However, lower survival rates on the hunted site could not be attributed to hunter kill, because no radio-marked females were bagged or reported by hunters and no evidence of hunter kill was observed. During this study, harvest appeared to be low in central Montana and appeared to have little impact on the population, especially relative to other mortality causes that were identified. Our results indicated costs of reproduction to survival.

Distribution of Swift Fox in the Proposed Valley County Wind Energy Project Area in Northeast Montana

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The initial stage of developing mitigation measures to minimize the impacts of energy development to wildlife is determining their distribution and abundance within the project area. We conducted a swift fox mark-recapture survey in the proposed Valley County Wind Energy Project (VCWEP) and surrounding area located approximately 30 miles north-northwest of Glasgow, Montana. Previous surveys have shown that swift fox have expanded into north-central Montana from Canada following reintroductions in southern Alberta and Saskatchewan. However, the extent of swift fox distribution within the proposed VCWEP and surrounding area was unknown. In 2005 and 2006, we systematically trapped 6 townships using Tomahawk live traps. We captured 4 swift fox in 2005 (2 adult males, 1 adult female, and 1 juvenile female) and 32 swift fox in 2006 (9 adult males, 10 adult females, 8 juvenile males, and 4 juvenile females) with capture rates of 1.3 percent and 14.5 percent, respectively. Within the VCWEP wind turbine footprint, we captured two swift fox in 2005 and six swift fox in 2006. This study determined that swift fox occupy the proposed VCWEP and surrounding area and provided information to aid the development of mitigation measures. The difference in capture rates between the two study years emphasizes the importance of multiple years of predevelopment data.

Off-Site and/or Compensatory Mitigation in Relation to Large Scale Development

Dan O. Stroud, Habitat Mitigation Biologist, Wildlife Division, Wyoming Game and Fish Department, P.O. Box 850, Pinedale, WY 82941

Several full-field developments, coupled with a USDI Bureau of Land Management (BLM) Field Office area with moderate to high potential for gas development in an area which maintains a world-class wildlife resource, has prompted the need for landscape scale

planning. In-fill development within the Jonah Field has led to companies providing compensatory mitigation funds in order to mitigate for impacts within the field that could not be avoided. Added development should necessitate the need for a landscape scale mitigation plan to identify how development should occur within the Upper Green River Basin; and how wildlife issues and mitigation funds should be utilized in order to address impacts and maintain wildlife resources. Development within SW Wyoming has prompted additional planning in the form of a SW Wyoming Landscape Initiative designed to examine these issues in a larger context. This paper will discuss mitigation needs on a landscape scale, as well as provide an update on a newly formed interagency office, was formed to address mitigation needs in relation to the associated development, primarily as it relates to those issues and species impacted in the Jonah Field. Finally, some discussion focused on planning needs that were not being addressed.

Wyoming Mitigation Concepts

Dan O. Stroud, Habitat Mitigation Biologist, Wildlife Division, Wyoming Game and Fish Department, P.O. Box 850, Pinedale, WY 82941

Energy has and continues to be one of Wyoming's primary economic engines; now perhaps more than ever. Currently, major development areas cover approximately 25 percent of the land area in the state. Within these areas, there are approximately 44,000 active wells, out of the 59,000 statewide. Some of these areas are currently going through the permitting process to greatly increase the amount of natural gas development. This increased development could easily be sustained over the next 30 years. Since most of this development also overlaps important wildlife habitats, it has forced the Wyoming Game and Fish Department to become proactive in dealing with these impacts and new approaches to mitigation. Some of these include 1) Working proactively with industry on individual plans to minimize and mitigate fish and wildlife impacts, 2) Working collaboratively with the BLM on the development plans, and on their Resource Management Plans to provide for greater consideration for wildlife, 3) Supporting the addition of a new office (Jonah Interagency Office) funded by industry, which will oversee and guide off-site mitigation, 4) Support for the hiring of an oil and gas coordinator in Pinedale, WY with funding provided by BLM and USFS, 5) Funding an Oil and Gas Coordinator Position in NE Wyoming, and 6) Working with our agency staff in terms of Department organization to shift personnel duties to address the issues associated with development. While all of these efforts have been somewhat effective, there is still a need for additional personnel time to address the expanding issues.

A Review of Energy Development in Montana; the How, What and Why

Dale Tribby, Supervisory Natural Resource Specialist, USDI Bureau of Land Management, Miles City Field Office, 111 Garry Owen Road, Miles City, MT 59301

Energy development may result in significant changes to Montana's landscape, especially on the plains of eastern and central Montana. This has resulted in questions as to the impact of these energy related activities on Montana's wildlife resources. To answer this question, we must first understand how much activity is currently permitted, what stipulations are attached to leases and how are Best Management Practices applied. In addition, through the Energy Act of 2005, pilot offices were established including one office in Montana (Miles City). What does it all mean?

A Synopsis of the Draft Supplemental Environmental Impact Statement Related to Coal Bed Natural Gas Development

Dale Tribby, Supervisory Natural Resource Specialist, USDI Bureau of Land Management, Miles City Field Office, 111 Garry Owen Road, Miles City, MT 59301

The Draft Supplemental Environmental Impact Statement (SEIS) is scheduled for release on 2 February 2007. As a result, thousands of federal wells have the potential to be drilled in the Powder River Basin of Montana. This presentation will address the anticipated level of development, management practices to be implemented and alternatives being considered. Information on submitting comments were presented.

Greater Sage Grouse Population Response to Energy Development and Habitat Loss

Brett L. Walker, David E. Naugle, and Kevin E. Doherty, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula, MT 59812

Modification of landscapes by energy development may alter both habitat use and vital rates of sensitive wildlife species. Greater sage grouse (*Centrocercus urophasianus*) in the Powder River Basin (PRB) of Wyoming and Montana are experiencing widespread, rapid changes to habitat due to recent coal-bed natural gas (CBNG) development. We analyzed lek count, habitat, and infrastructure data to test how CBNG development and other landscape features influenced sage-grouse population trends and lek status in the PRB. From 2000-2005 leks in CBNG fields showed lower trends in population indices and 11-55 percent fewer males per active lek than leks outside CBNG development. Among lek complexes of known status in 2004-2005, only 34 percent remained active within CBNG fields, compared to 82-83 percent of leks adjacent to or outside CBNG, and all remaining large and medium-sized leks (≥ 25 males) occurred outside CBNG. Lek-complex persistence was positively influenced by the proportion of sagebrush habitat and negatively influenced by the proportion of tillage agriculture at large scales around leks. After controlling for habitat loss, lek-complex persistence was also negatively influenced by the extent of CBNG development at all scales, with the strongest effects occurring within 0.8 km. Maintaining sage grouse populations in areas with CBNG likely will be difficult without a major shift in mitigation strategies toward spatial, rather than temporal restrictions on development, and rapid implementation of enhanced industry-wide standards for mitigation. Our findings also emphasized a need for government agencies to set population goals for conservation and conduct landscape-scale conservation planning for sensitive wildlife species prior to energy development.

Highlights from 15 Years of White-Tailed Deer Research in Northwestern Montana

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White-tailed deer (*Odocoileus virginianus*) are the most abundant big game species in northwest Montana, accounting for more than 75 percent of annual deer harvests in Montana Fish, Wildlife and Parks' (FWP) Region 1. FWP initiated a study in 1988 in the Salish Mountains to better define ecological relationships of white-tailed deer occupying conifer-dominated winter ranges in northwest Montana. Data collection spanned the period of 1988-2000; however, collection of harvest records continued through 2003. Most white-tailed deer in the Salish Mountains typically migrated ~20-30 km (12-19 mi) between summer ranges consisting of higher elevation forest and meadows and winter ranges in lower valleys with relatively dense coniferous cover. Patterns of resource use supported a hypothesis that deer enhance survival by adopting a strategy of energy conservation during most winters. Dense tree canopy intercepts snowfall and hence reduces energetic costs of movement and likely enhances ability to evade predators. Overall deer density in the Salish Mountains ranged from 2.3-10.8 deer/km^2 (6-28 deer/mi^2) with densities on winter range from 130-205 deer/km^2 (116-530/mi^2). We conclude that variation in female survival operated independently of recruitment to drive population trend of white-tailed deer in the Salish Mountains. More detailed results of this work are available in the recently completed report titled: White-tailed Deer Studies in the Salish Mountains, Northwest Montana, published by FWP.

Large-Scale Genetic Structure of Black-Backed Woodpeckers

Jennifer C. Woolf, Wildlife Biology Program, University of Montana, Missoula, Montana 59812

The black-backed woodpecker is a naturally rare, wide-ranging woodpecker that inhabits recently burned forests. Due to their natural rarity, little is known regarding black-backed woodpecker movement patterns and population structure. Genetic techniques allow us to measure population structure without intensive fieldwork, such as mark-resight methods. In general, avian populations show little genetic differentiation due to high rates of dispersal, often over exceedingly large distances. This fact, combined with the ephemeral nature of black-backed woodpecker habitat, has led us to predict that black-backed woodpeckers would have little genetic differentiation, even at large geographic scales. In contrast, we have found substantial genetic differentiation along an east/west gradient for birds sampled in Oregon, Idaho, Montana, South Dakota, and Alberta for mitochondrial DNA. However, there was little evidence of genetic differentiation along a north/south gradient within the Rocky Mountains. We detected three main groups of populations: West (Oregon), Mid (Idaho, Montana, and

Alberta), and East (South Dakota). We are currently examining nuclear loci, which will be used in combination with our current mtDNA results, to determine if these groups should be managed as distinct population segments or separate management areas.

Patterns and Rates of Wolverine Movement Using GPS Technology in Glacier National Park, Montana

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Documentation of wolverine presence in remote areas has been carried out using winter track surveys. Description of wolverine travel patterns and rates of travel have been based on anecdotal evidence at best. During the past 4 yrs we captured and instrumented 22 wolverines in Glacier National Park. Of these, five individuals have successfully carried Lotek store-on-board GPS collars for periods of up to several months, and have provided nearly 10,000 data points. A high recapture rate provided an opportunity to reinstrument individuals with varying GPS acquisition rates within a single trapping season. Initial GPS location data were programmed for a 4-hr cadence, but wolverine movement rates at this interval did not provide adequate information on travel paths and patterns and indicated a need for a finer scale fix rate. We varied the frequency of GPS fix attempts at 4 hours, 2 hours, 30 min, and 5 min as we recaptured study animals. Subsequently most data sets were programmed to collect GPS locations at 5-min intervals, 24 hrs/day, 7 days/wk. Analysis of these fine-scale data reveals travel paths and corridors, as well as rates and patterns of travel for wolverines astride the Continental Divide in alpine and subalpine sections of Glacier National Park.

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Design and Layout ~ **Media Works, Bozeman, Montana**

Printi g ~ **Bozeman Printing Company, Bozeman, Montana**

Intermountain Journal of Sciences

Vol. 13, No. 4 - 2007

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