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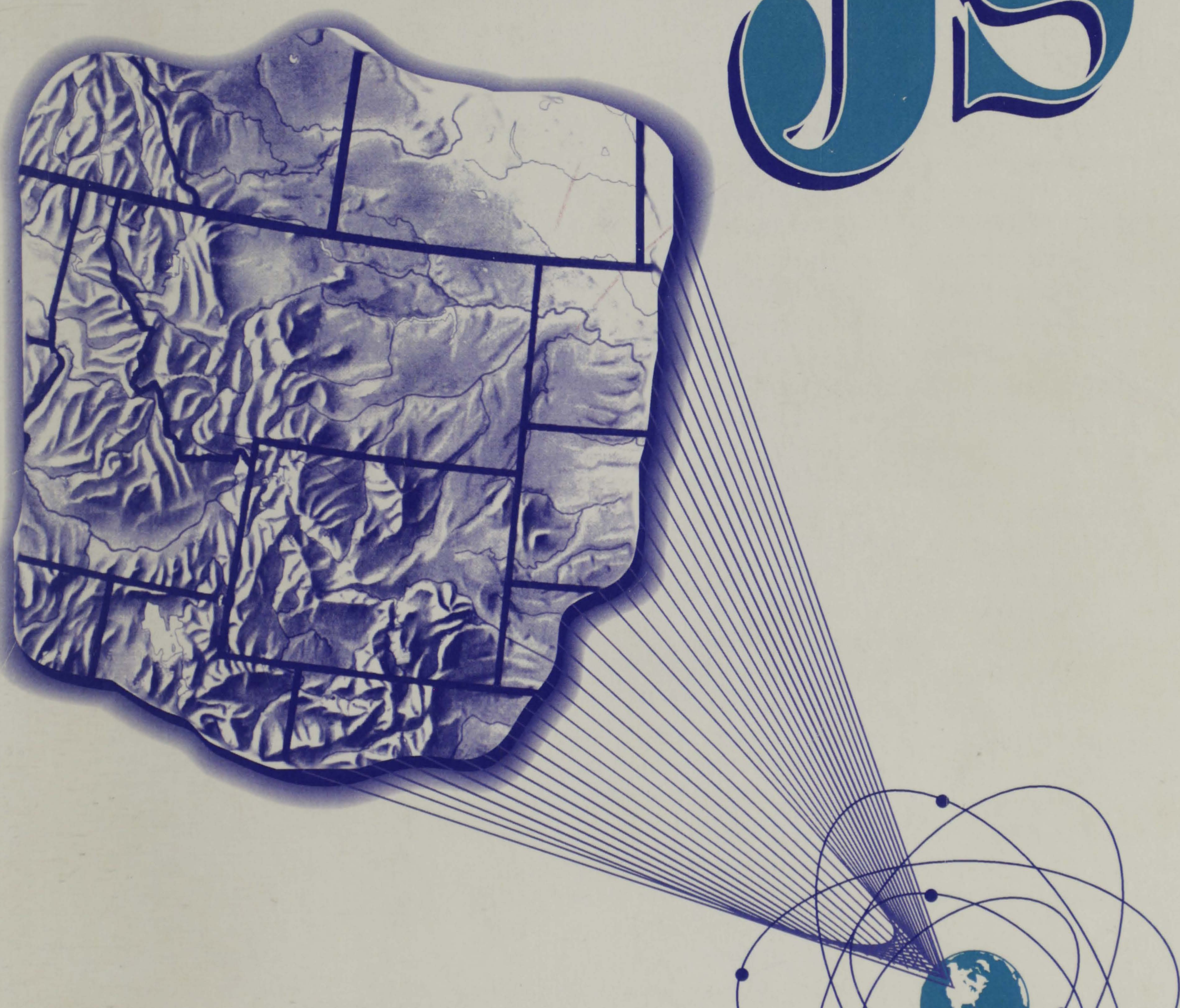

INTERMOUNTAIN JOURNAL OF SCIENCES

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

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

Initial funding was provided by the co-sponsor organizations. Long-term funding will be derived from page charges assessed authors, sponsoring organizations or agencies at $45 per printed page upon acceptance of each manuscript and from annual subscriptions: student $6; regular member $15; patron member $25; library $25; life member $150; and, sustaining subscriber $2,500.

The intent of the co-spon or 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 Manuscript Submitted to the Intermountain Journal of Science , Dusek 1995*.* Organization may vary to accommodate the content of the article, although the text is expected to elucidate application of result .

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www.montanatws.org/ijsindex.html

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Financial Statement (01/01/01 through 12/31/01)

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Income

Regular Member	1,290.00
Student Member	18.00
Library Subscription	425.00
Patron Member	25.00
Subscription Total	$1,758.00
Page Charges	4,755.00
Reprints	1,584.64
Back Issue Sales	55.00
Grants *	5,904.93
Refund	6.00
Total Income	$14,063.57

Expenses

Design and Printing	15,348.66
Mailing Service	190.60
Postage	584.11
Supplies	14.74
P.O. Box Rent	80.00
Bank Fees (new checks)	16.90
Reprints and Layout	1,145.57
Website Maintenance	225.00
Total Expenses	$17,605.58

Accts Payable 12/31/01 .... $1,046.30

Balance 12/31/01 .... $-734.41

*Grantors: Idaho Fish and Game, Henry's Fork Watershed Fund, State of Montana, USDA Forest Service

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). This cover letter must also include a statement by the author that this paper has not been submitted for publication or published elsewhere. The EIC notes the date of receipt of the manuscript and assigns it a reference number, IJS-xxxx. The EIC forwards a letter of manuscript receipt and the reference number to the corresponding author. The corresponding author is the author who signed the submittal letter.

Three hard copies of the submitted manuscript with copies of the "Guidelines and checklist for IJS referees" attached are forwarded to the appropriate Associate Editor. The Associate Editor retains one coy of the manuscript and guidelines for his/her review, and submits a similar package to each of two other reviewers. A minimum of two reviewers including the Associate Editor, is required for each manu cript. 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 M 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. Guidelines for manuscripts submitted to the *Intermountain Journal of Sciences*. Int. J. Sci. 1(1):61-70.

Send all manuscripts to: Editor-in-Chief, P.O. Box 3014, Bozeman, MT 59772-3014

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Abstracts

Design and Layout ~ **Media Works, Bozeman, Montana**
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Effect of Predator Control on Coyote Age Structure, Weight, and Reproduction

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Abstract

Predator control on coyotes (*Canis latrans*) has been extensive throughout the western United States. A common biological expectation is that reproduction increases as density of coyotes is reduced. However, this expectation does not consider social structure, age structure, or prey availability before and after predator control is undertaken. We examined the effects of predator control on coyote age structure, weight, and reproduction in three study units in north-central Montana. Study units ranged from 140 to 2679 km^2 and were subjected to different levels of control intensity. Coyote age structure did not change significantly over time within individual units. Among treatment areas, only the area most intensively controlled differed significantly in age structure, having younger coyotes. Based on corpora luteal counts, coyote reproduction increased only within the largest unit, which was subjected to intense control. Coyotes were younger, larger, and more reproductively active when subjected to intensive control over a large area. Significant differences in age or reproduction were not apparent for units of smaller size or less intensive control efforts.

Key Words: age structure, *Canis latrans,* Coyote, predator control, reproduction.

Introduction

Since the extirpation of larger carnivores, such as grizzly bears (*Ursus arctos*) and wolves (*Canis lupus*) within the majority of livestock producing areas of the western United States, coyotes (*Canis latrans*) have been a primary target of predator control activities. Recent declines in deer (*Odocoileus* spp.) and pronghorn antelope (*Antilocapra americana*) populations and reintroduction of black-footed ferrets (*Mustela nigripes*) in Montana led to predator control activities in an attempt to provide increased survivorship of those species.

The effectiveness of predator control on survival of prey populations has been the subject of much study and debate (Schladweiler 1980, Stout 1982, Guthery and Beasom 1997, Hamlin 1997, Sacks et al. 1999, Wagner and Conover 1999, Ballard et al. 2001). However, little information is available on the reproductive response of coyotes to prolonged coyote control. Knowlton (1972) developed a model to predict the response of coyote populations subjected to control that assumed, under favorable conditions, reproductive rates would increase as density decreased. An expected biological response of increased reproduction was predicated on decreased intraspecific competition for resources. This assumption did not consider the influence of changes in social structure of coyotes, potential differences in reproduction due to altered age structure, or status of the current population in terms of resource allocation. Reproductive rates generally vary depending on age, food availability, and social status (Bekoff 1982, Voight and Berg 1987). The percentage of sexually mature females, ovulation rate, degree of successful implanting, and *in utero* viability are important variables in determining coyote reproductive rates (Knowlton 1972). Coyotes are able to reproduce as juveniles (< 1 year old), but conception rates and litter sizes are variable (Todd et al. 1981, Voight and Berg 1987).

Reproductive rates of coyotes may be inversely related to population density. Knowlton (1972) observed an increase in mean litter size with decreasing coyote densities in Texas. Although many factors may affect individual reproduction, the relationship between coyote density and reproductive rate may be significantly influenced by competition for food resources. Clark (1972) documented fluctuations in Wyoming coyote populations in relation to variations in jackrabbit (*Lepus* spp.) populations.

We examined the effect of predator control on coyote reproductive rates, age structure, and weight. The study was conducted in conjunction with predator control activities designed to achieve specific management goals associated with wild ungulate survival and black-footed ferret reintroductions.

STUDY AREA

The study area consisted of three units within central and north-central Montana (Fig. 1): (1) The Charles M. Russell/UL Bend National Wildlife Refuge and surrounding Bureau of Land Management and private lands of north central Montana (CMR/BLM unit); (2) the Fort Belknap Indian Reservation and private lands to the east (FB unit), also in north-central Montana; and (3) the eastern one-half of hunting district 530 (HD 530 unit) as described in the Montana deer hunting regulations located northeast of Roundup in central Montana.

The CMR/BLM unit was nearly 1620 km^2 in size during the initial 1993 and 1994 sampling sessions, but was reduced to approximately 140 km^2 surrounding black-footed ferret release sites on the UL Bend National Wildlife Refuge for subsequent sampling efforts. Timbered drainages or "coulees" of the Missouri River breaks, surrounded by elevated sagebrush (*Artemisia* spp.) prairie comprise the major habitat features of the CMR/BLM unit. Ponderosa pine (*Pinus ponderosa*) and Rocky Mountain juniper (*Juniperus scopulorum*) comprise the coniferous trees within and along coulees and cottonwood (*Populus* spp.) and willow (*Salix* spp.) occurred in riparian areas. Elevations ranged from approximately 630 m at Fort Peck Reservoir to 948 m on prairie uplands. Average annual precipitation was 29.8 cm

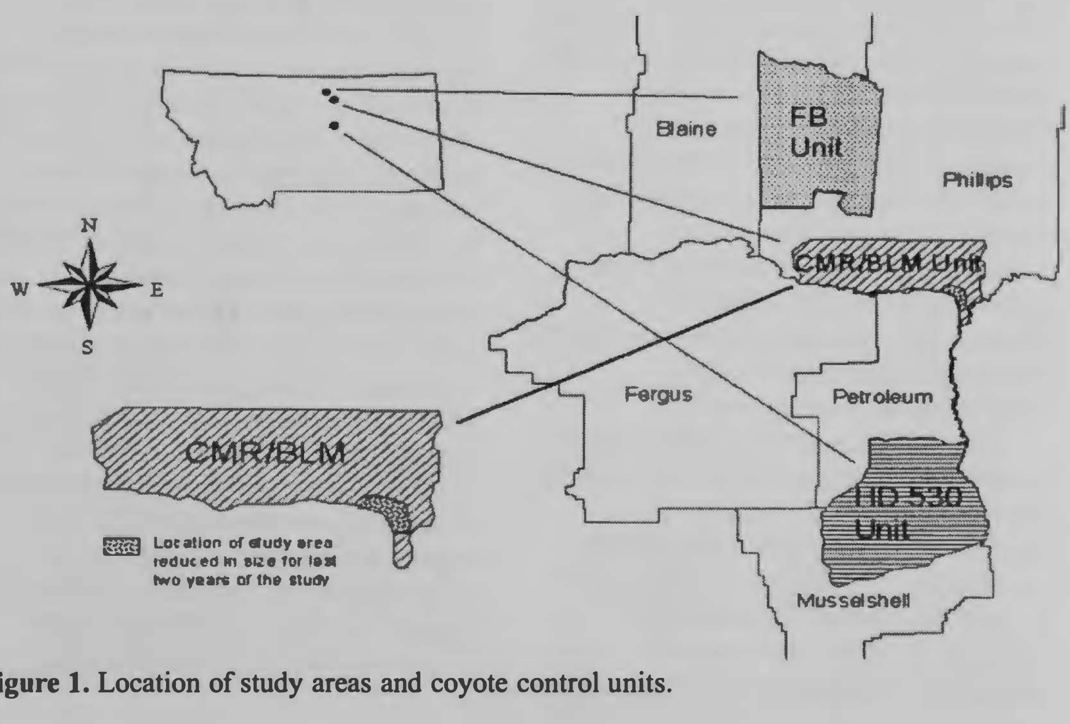

Figure 1. Location of study areas and coyote control units.

for the CMR/BLM area (Western Regional Climate Centers [WRCC] 2000). Livestock grazing and small grain farming were the primary agricultural uses of private and Bureau of Land Management property. The CMR/BLM's southern boundary was the Missouri River and Fort Peck Reservoir.

Sagebrush prairie with isolated timbered buttes and brush-laden creek bottoms comprised the major habitats of the nearly 2460 km^2 FB unit. Ponderosa pine and Rocky Mountain juniper dominate the overstory of the buttes and cottonwood and willow persist along creek drainages. Elevations range from 720 to 800 m, and the area received an average of 29.8 cm of precipitation annually (WRCC 2000). Agricultural use within FB occurred primarily in the form of prairie rangeland and small grain farming.

HD 530 was the largest unit, approximately 2679 km^2, and consisted of riparian, agricultural, timbered breaks, and sagebrush prairie habitats. Alfalfa production occurred primarily in conjunction with riparian areas, whereas small grain farming was interspersed with native prairie uplands. Timbered breaks, dominated by ponderosa pine, were associated with creek drainages feeding the Musselshell River. Annual precipitation was approximately 33 cm (WRCC 2000) with elevations ranging from 720 to 800 m.

Methods

Coyotes were killed through aerial gunning from helicopter and fixed-wing aircraft by Animal Plant Health Inspection, Wildlife Services (WS) personnel, as well as by trapping and free-hand shooting from the ground. Coyotes killed by use of a helicopter were delivered to a ground crew where they were weighed and necropsied. A spring scale was used to determine weights to the nearest kilogram. We collected skulls or jaws and removed a canine from which age was assigned by cementum analysis at Matson's Laboratory, Milltown, MT. Ages were recorded in increments of 0.5 years. A juvenile was recorded as 0.5 years old, a yearling as 1.5 years old, and a coyote with a cementum analysis of 2 was considered 2.5 years old.

We prosected reproductive tracts from female coyotes in the field or at the Montana Fish, Wildlife and Parks, Wildlife Research Laboratory (MFWPWL). We examined reproductive tracts from females ≥10 months old but excluded those from juveniles that were harvested during the summer/fall as they would not have had the opportunity to breed. Reproductive tracts were fixed in 10-percent buffered formalin and transported to the MFWPWL where ovary pairs were excised and weighed. We hand sectioned ovary pairs collected in the winter of 1993 and counted the corpora luteal scars (CL). All ovary pairs collected after 1993 were packed in water and sent to Matson's Laboratory, Milltown, MT, for histological sectioning and staining. There, they stained ovarian tissue with hematoxlyin/eosin, sectioned them every 200 microns, and mounted sections on a slide. We conducted CL counts at the MFWPWL by examining the slides under a 40X-power microscope. Age of reproduction was the coyote's age during the last breeding season. For example, a yearling coyote collected in summer/fall would have been a juvenile during the breeding season earlier in the year, and if CL were present, we recorded that individual as being bred as a juvenile.

Coyote control activities on CMR/BLM and FB were conducted to enhance black-footed ferret reintroductions and conduct disease surveys. Coyotes were killed in HD 530 to examine the effects of predator control on survival and recruitment of deer and antelope. The study areas were subjected to different levels of predator harvest prior to implementation of the study. The CMR/BLM was subjected to limited coyote harvest consisting primarily of hunter-killed animals, incidental to deer and elk hunting seasons. We did not consider harvest rates to measurably affect the population prior to the study. Coyote harvest on the FB study area occurred primarily from tribal members opportunistically harvesting coyotes.

Coyote mortality prior to implementation of this study was likely more intensive than on the CMR/BLM but not consistent or directed. HD 530 was subjected to the most intensive coyote control prior to implementation of the study. Coyotes within HD 530 were harvested by aerial gunning by WS from a fixed-wing aircraft and hunting or trapping by local ranchers to reduce livestock losses. Coyote control action by WS in response to livestock depredation resulted in an average annual removal of approximately 89 coyotes (0.03/ km^2) from the study area in the three years prior to initiation of the study.

Aerial gunning from a helicopter on the CMR/BLM unit occurred in late winter/ early spring (winter/spring) and late summer/early fall (summer/fall). Winter/ spring sampling periods focused on a general disease survey, and harvest consisted of few coyotes collected from varying locations throughout the area. The intent of collections during the summer/fall periods also was a disease survey with increased effort aimed at reducing predator numbers. Collections started in winter 1993 and continued through fall 1996. Winter/ spring collections in 1993 and 1994 occurred over a large geographic area (1620 km^2) surrounding the black-footed ferret reintroduction area. Due to management concerns, collections starting during summer/fall 1995 were intensified but confined to a 140-km^2 area immediately within and surrounding the ferret release site on the CMR/BLM (Fig. 1). An effort was made to harvest all coyotes within the 140-km^2 study area. We did not conduct a summer/fall collection in 1993, reproductive data were not available for 1994, and winter/spring sampling was not conducted during 1996.

Coyote control was conducted on FB from 1993 through 1998. The study site remained constant in size throughout the study, and effort was made to collect all available coyotes. Helicopter collections on FB occurred during winter/spring of 1993, 1994, and 1995 and during both sampling periods in 1996, 1997, and 1998. Reproductive tracts were not available for 1994 or 1995, and weights were not available for 1995. Additional coyotes were killed through aerial gunning from a fixed-wing airplane in 1997 and 1998, but these carcasses were not available for examination.

Coyote control in HD 530 was intensified, starting in 1997, to stimulate or increase deer and antelope survival. Hunting from fixed-wing aircraft was increased and a helicopter was used to kill coyotes during a one-week period in March. Only coyotes killed by use of a helicopter during March 1997-1999 were available for examination.

We used Analysis of Variance (ANOVA) to test for significant differences among mean ages, weights, and CL counts. We conducted Chi-square tests to determine if sex ratios differed significantly from parity. We used the 95 percent Least Squares Multiple Range (LSD) test to determine differences among units and sampling years for age, weight, and CL counts when significant differences were detected using ANOVA. Coyotes were grouped into two age classes: juveniles (<1 year old) and adults (≥1 year of age) for analysis of weight and CL counts. We used a P-value ≤ 0.05 to determine whether differences were significant for all tests.

Results

CMR/BLM Unit

Two hundred, ninety-six coyotes were killed on the CMR/BLM unit by aerial gunning, trapping, and shooting from the ground from 1993 through 1996. A helicopter was used to collect 294 coyotes that averaged 15.5 coyotes/day. Total coyote harvest during 1993 and 1994 on the larger 1640-km^2area averaged 0.04 coyotes/km^2/ year. Subsequent collections on the 140-km^2area increased in intensity and averaged 0.64 coyotes/km^2/year. We determined sex for 284 carcasses, which had a combined sex ratio of 142 males and 142 females. Slight variation occurred among years but sex ratio was not different from parity for any year ($P > 0.05$) (Table 1).

Table 1. Sex ratios of coyotes collected on the CMR/BLM, FB, and HD 530 units from 1993 through 1999. NC indicates a year when collections did not occur.

Year		1993	1994	1995	1996	1997	1998	1999	Total
CMR/BLM	Female	28	32	50	32	NC	NC	NC	142
	Male	25	30	51	36	NC	NC	NC	142
FB	Female	15	15	9	16	21	40	NC	116
	Male	14	18	11	16	25	41	NC	125
HD 530	Female	NC	NC	NC	NC	18	12	7	37
	Male	NC	NC	NC	NC	29	14	10	53

Age structure for all years combined was 37 percent juveniles (105), 22 percent yearlings (63), and 41 percent adults (116). Average age, pooled for 1993, 1995, and 1996, was 2.52 for females (n = 142) and 2.25 for males (n = 142) but was not different (P = 0.33, F = 0.96, df = 283). Mean age, with males and females pooled for each year, ranged from a low of 2.1 years in 1994 (n = 62) to a high of 2.7 years in 1996 (n = 68). However, mean age did not differ among years (P = 0.37, F = 1.06, df = 283) (Fig. 2).

Mean weight of adult males collected during summer/fall was significantly greater ($\bar{x}$ = 13.5 kg, n = 40) than those of winter/spring ($\bar{x}$ = 12.6 kg, n = 24) (P = 0.03, t = 4.56, df = 218). Mean weight of adult males increased with successive years but did not differ significantly (P = 0.13, F = 1.98, df = 63) (Fig. 3). Mean weight of adult females did not differ (P = 0.48, t = 0.52, df = 82) between winter/spring ($\bar{x}$= 11.2 kg, n = 32) and summer/fall ($\bar{x}$= 11.4 kg, n = 51) or among years (P = 0.51, F = 0.77, df = 82) (Fig. 4). Mean weight of adult females was lower than the mean for adult males (P < 0.05, F = 64.72, df = 146) when all years and seasons were pooled.

Mean weight for pooled male and female juveniles differed among years for winter/spring (P = 0.03, F = 3.80, df = 34) and summer/fall (P= 0.03, F = 4.11, df = 36). Mean juvenile weight for winter/spring ranged from 10.6 kg in 1996 (n = 6) to 12.1 kg in 1994 (n = 15) and was consistently greater than summer/fall weight which ranged from 6.6 kg (n = 10) in 1994 to 8.4 kg (n = 8) in 1995.

Mean number of CL scars on ovaries from breeding age females did not differ among years for the CMR/BLM unit (P = 0.33, F = 1.11, df = 81). Mean CL counts ranged from 2.21 in 1993 (n = 24) to 1.15 CL per female in 1995 (n = 22) (Fig. 5). No CL were observed in the nine juveniles examined in 1993. One of 11 ovary pairs from juveniles in 1995 and one of seven ovary pairs in 1996 contained CL. Juveniles with CL present comprised 4.5 percent of the 1995 (n = 22) and 3.8 percent of the 1996 (n =26) reproductive age females harvested. Juveniles were prevalent in the harvest, comprising 37.5 percent, 50.0 percent, and 26.9 percent of the reproductive age females examined on the CMR/BLM unit in 1993, 1995 and 1996, respectively (Table 2), but did not contribute substantially to reproduction.

FB Unit

We determined the sex of 241 of 252 coyotes killed by aerial hunting in the FB unit. Helicopter harvest rates over the six years of the study averaged 16.8 coyotes/ day (n = 241) resulting in a yearly average take of 0.02 coyotes/km^2. The pooled sex ratio for all years (125 males: 116 females)

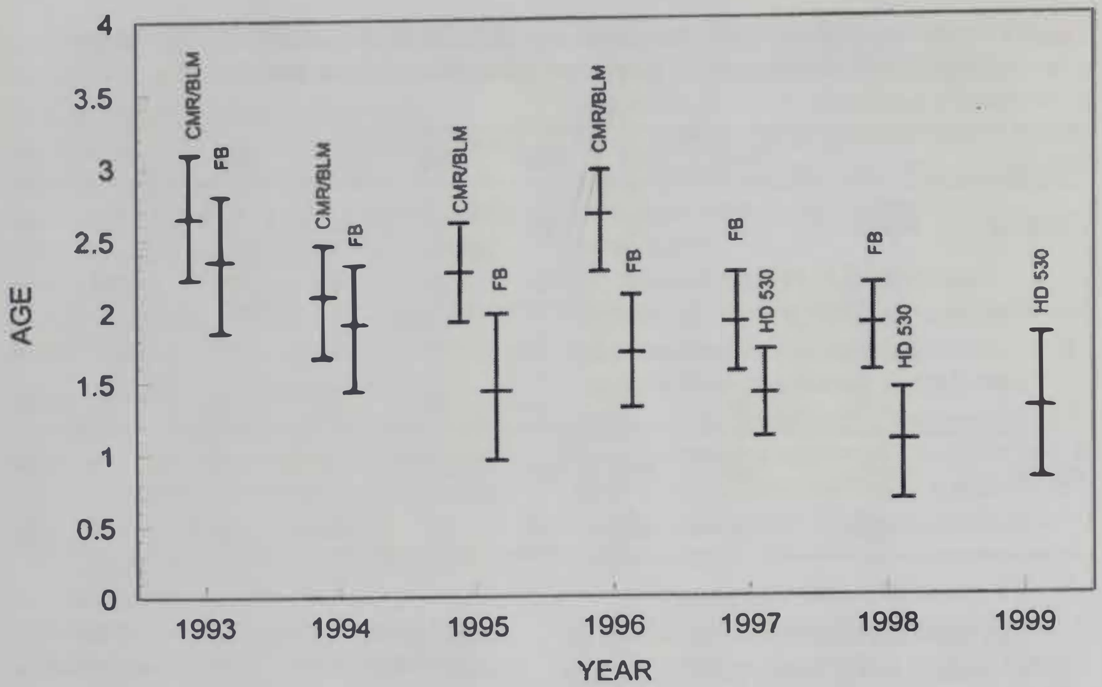

Figure 2. Mean ages and 95 percent confidence intervals of coyotes collected on the CMR/BLM, FB, and HD 530 study units. Male and female coyotes were pooled within each year.

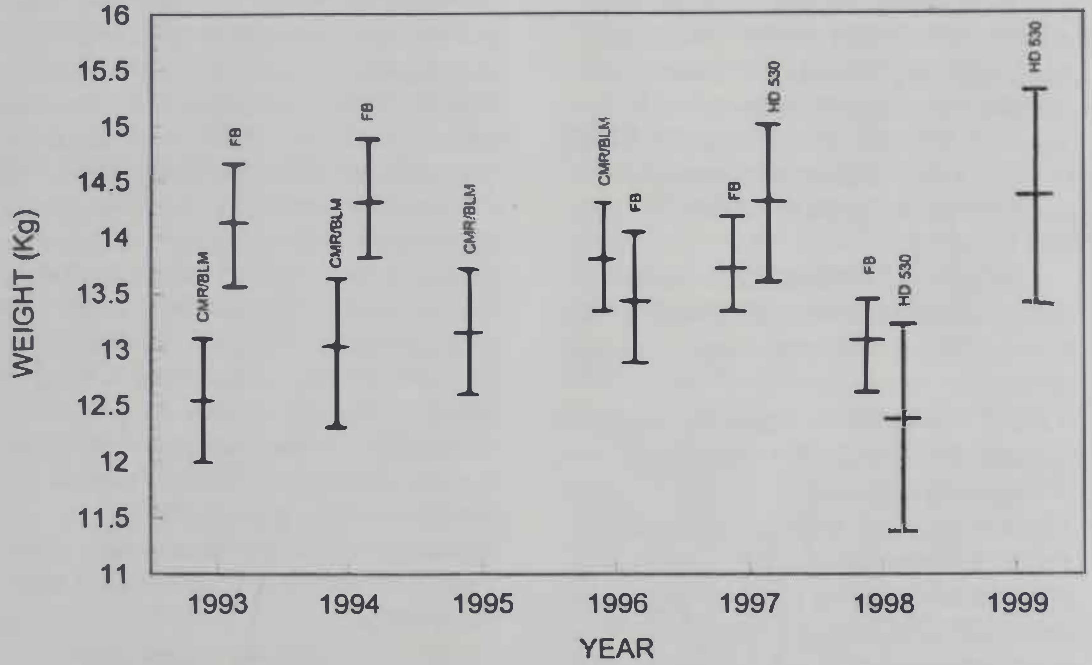

Figure 3. Mean weights and 95 percent confidence intervals for adult male coyotes collected on the CMR/BLM, FB, and HD 530 study units.

did not differ from parity ($P > 0.05$, $X^2 = 0.336$, df = 1). Sex ratio also did not differ among years ($P > 0.05$) (Table 1).

Juveniles, yearlings, and adults comprised 39, 25, and 36 percent, respectively, of the 232 coyotes aged. Mean age for females ($\bar{x} = 1.93$, $n = 113$) was not different than for males ($\bar{x} = 1.86$, $n = 119$) ($P = 0.74$, $t = 0.11$, df = 231) when all years were pooled. Mean age for all coyotes collected during 1993 was 2.33 ($n = 29$) years. Mean age then decreased by year

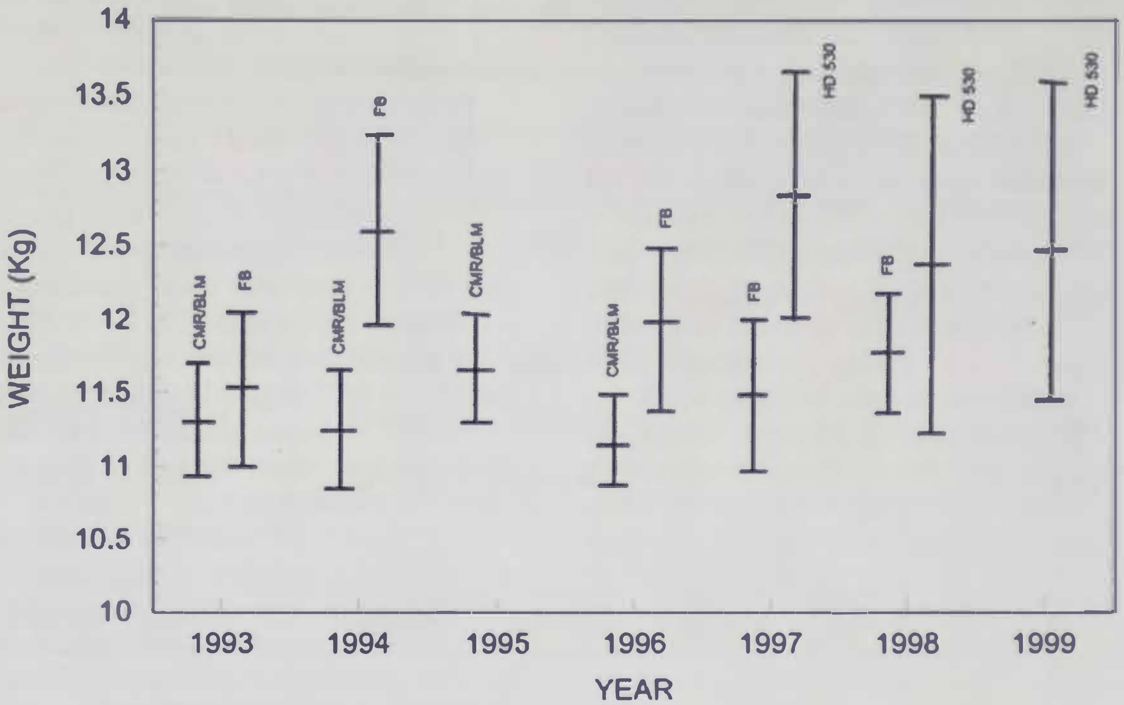

Figure 4. Mean weights and 95 percent confidence intervals by year for adult female coyotes collected on the CMR/BLM, FB, and HD 530 study units.

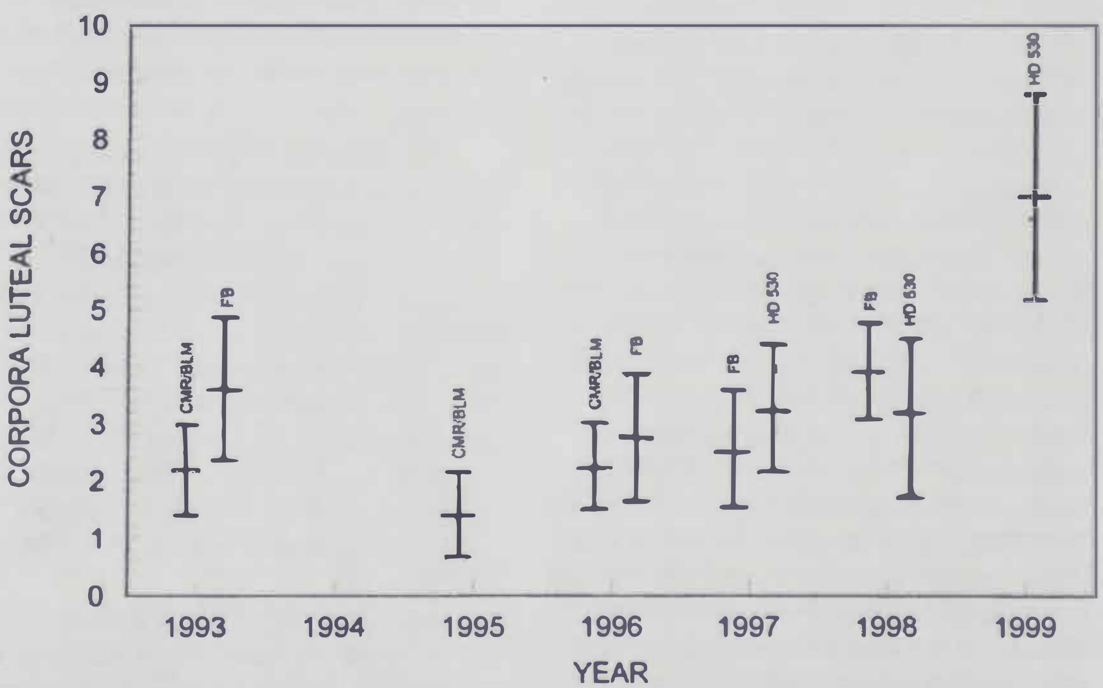

Figure 5. Mean number of CL and 95 percent confidence intervals observed in females collected on the CMR/BLM, FB, and HD 530 study units.

Table 2. Reproductive tracts examined by age class for the CMR/BLM, FB and HD 530 units. The percentage of ovaries containing CL scars is presented within the ( ).

Unit	CMR/BLM		FB		HD 530	
Age Class	JUV.	AD.	JUV.	AD.	JUV.	AD.
1993	9 (0%)	15 (60%)	2 (0%)	11 (82%)		
1995	11 (9%)	11 (54%)				
1996	7 (14%)	19 (79%)	5 (0%)	11 (73%)		
1997			10 (0%)	9 (89%)	11 (36%)	7 (100%)
1998			11 (18%)	18 (94%)	8 (38%)	4 (100%)
1999					3 (67%)	4 (100%)
TOTAL	27 (7%)	45 (67%)	28 (7%)	49 (86%)	22 (41%)	15 (100%)

until reaching a low of 1.45 years in 1995 (n =20) and rebounded in 1997 (n = 46) and 1998 (n = 73) to 1.91 years of age. Differences among years were not significant (P = 0.59, F = 0.75, df = 231) (Fig. 2).

Mean weight of adult males did not differ between winter/spring ($\bar{x}$ = 13.8 kg, n = 46) and summer/fall ($\bar{x}$ = 13.2 kg, n = 16) seasons (P = 0.07, t = 3.30, df = 61) but did differ among years (P = 0.04, F = 2.77, df = 61) (Fig. 3). Mean weight of adult females did not differ between sampling season (P = 0.06, t = 3.72, df = 65) or among years (P = 0.33, F = 1.17, df = 65) (Fig. 4). Adult males ($\bar{x}$ = 13.6 kg, n = 62) weighed more than adult females ($\bar{x}$ = 11. 8 kg, n = 66) when all years and sampling seasons were combined (P < 0.05, t = 68.76, df = 127). Mean weight of juveniles ranged from 11.2 to 12.3 kg during winter/spring, but did not differ among years (P = 0.1401, F = 1.81, df = 62). Juveniles collected in 1997 were heavier ($\bar{x}$ = 8.3 kg, n =3) than those collected in 1998 ($\bar{x}$ = 6.6 kg, n = 16) during summer/fall (P < 0.05).

A total of 77 breeding age females were examined from the FB unit (Table 2). Mean CL counts varied from 2.5 in 1997 (n = 19) to 3.9 in 1998 (n = 29) (Fig. 5), but differences among years were not significant (P = 0.40, F=0.99, df = 76). Juveniles comprised 15, 31, 53, and 38 percent of the females sampled in 1993, 1996, 1997 and 1998, respectively. We observed no evidence of reproduction by juveniles except during 1998 when 2 of 11 (18%) juvenile ovaries contained CL.

HD 530

We examined 90 of 315 coyotes killed through aerial gunning in HD 530 from 1997 through 1999. The 90 coyotes examined were killed with the use of a helicopter, averaged six coyotes/day, and resulted in a density of 0.04 coyotes/km^2 killed/year. The remaining coyotes were shot from a fixed-wing aircraft. Males predominated in the sample (59 %), but sex ratios did not differ from parity within individual years (P > 0.05) or when all years were pooled (P > 0.05, X^2 = 2.84, df = 1) (Table 1).

Juveniles comprised 62 percent of the 90 carcasses examined, while yearlings and adults made up 20 percent and 18 percent, respectively. Mean age of males (1.16, n = 53) was not different (P = 0.23, t = 1.44, df = 89) than mean age of females (1.53, n = 37). Mean age of coyotes ranged from a low of 1.08 in 1998 to a high of 1.44 in 1997 but did not differ ($P = 0.59$, F = 0.52, df = 89) among years (Fig. 2).

HD 530 was not sampled during summer/fall precluding comparisons between seasons. Mean weights of adult males differed ($P = 0.04$, F = 3.91, df = 18) among years (Fig. 3). Based on LSD analysis, weights during 1998 were significantly lower than those of 1997 and 1999 ($P < 0.05$). Mean weight for adult females (Fig. 4) ranged from 12.4 kg in 1998 ($n = 4$) to 12.8 kg in 1997 ($n = 7$) and did not differ among years ($P = 0.853$, F = 0.16, df = 14). Adult males were heavier ($\bar{x}$ = 13.8 kg, $n = 15$) than females ($\bar{x}$ = 12.6 kg, $n = 19$) ($P = 0.03$, F = 5.44, df = 33). Juvenile coyotes collected on HD 530 from 1997 through 1999 ranged in weight from 11.2 kg in 1998 ($n = 17$) to 12.6 kg in 1997 ($n = 29$). Mean weight of juveniles differed among years ($P = 0.02$, F = 4.18, df = 53). Juveniles harvested in 1997 were significantly heavier than in 1998 ($P < 0.05$), but juveniles harvested in 1999 did not differ from either 1997 or 1998.

We examined 37 female reproductive tracts from HD 530 (Table 2). Juveniles comprised 59 percent of the total sample and 61, 67 and 43 percent of the ovaries examined in 1997, 1998 and 1999, respectively. Juvenile ovaries containing CL comprised 36 percent of the 1997 ($n = 11$), 43 percent of the 1998 ($n = 7$), and 33 percent of the 1999 ($n = 6$) samples in which CL were observed. The percentage of the juvenile cohort with CL present in ovaries increased annually from 36 percent in 1997 ($n = 11$) to 38 percent in 1998 ($n = 8$), and 67 percent in 1999 ($n = 3$). CL counts differed among years ($P = 0.03$, F = 3.75, df = 36) (Fig. 5). CL counts in 1999 ($\bar{x}$= 7.0, $n = 7$) were greater than 1997 ($\bar{x}$ = 3.3, $n = 18$) and 1998 ($\bar{x}$ = 3.2, $n = 12$) ($P < 0.05$), but 1997 and 1998 did not differ ($P > 0.05$). However, sample sizes were small.

Unit Comparison

Males predominated on FB and HD 530 when all years were pooled; however, sex ratios did not differ from parity ($P > 0.05$). Sex ratios of harvested coyotes were equal on the CMR/BLM unit.

Mean age of coyotes from the three units differed ($P < 0.05$, F=11.17, df =607) when all years were pooled. HD 530 had the lowest cumulative mean age of 1.31 ($n = 90$), followed by FB at 1.90 ($n = 241$) and CMR/BLM with a mean age of 2.30 ($n = 284$) years. Based on LSD analysis all units differed significantly from each other ($P < 0.05$) (Fig. 6).

Mean weight of adult males differed ($P_m = 0.002$, F = 6.64, df = 89) among the three units during the winter/spring when all years were pooled. Weight of adult males was lower ($P < 0.05$) for coyotes collected on the CMR/BLM ($\bar{x}$ = 12.6 kg, $n = 32$) than on FB ($\bar{x}$ = 13.8 kg, $n = 54$) or HD 530 ($\bar{x}$ = 13.8 kg, $n = 19$) but did not differ between FB and HD 530 ($P > 0.05$). Mean weight of adult females also differed among the three units during winter/spring (P_f= 0.002, F = 6.97, df = 100). Mean weight of adult females on the CMR/BLM ($\bar{x}$ = 11.2 kg, $n = 32$) was lighter during winter/spring then those from the FB ($\bar{x}$ = 11.9 kg, $n = 54$) or HD 530 ($\bar{x}$ = 12.6 kg, $n = 15$) units ($P < 0.05$). Mean weight of adult females during winter/spring on FB and HD 530 did not differ ($P > 0.05$) from mean weight of adult males.

Mean weight of neither adult females nor adult males differed between CMR/BLM and FB during summer/fall ($P_f = 0.52$, $t = 0.42$, df = 62; $P_m = 0.46$, $t = 0.55$, df = 55). Mean weight of adult females was 11.4 kg ($n = 51$) on CMR/BLM and 11.2 ($n = 12$) on FB. Adult male weights averaged 13.5 kg ($n = 40$) and 13.2 ($n = 16$) on the CMR/BLM and FB respectively.

Mean CL counts differed among units when all years of collection were pooled ($P = 0.003$, F = 6.18, df = 185). Female coyotes on the CMR/BLM unit had a mean CL count of 2.0/female, the lowest among the three units. Mean CL counts were 3.3/female on FB and 3.9/female in HD 530 (Fig. 7). FB and HD 530 did not differ from each other ($P > 0.05$) but they did differ from CMR/BLM ($P < 0.05$).

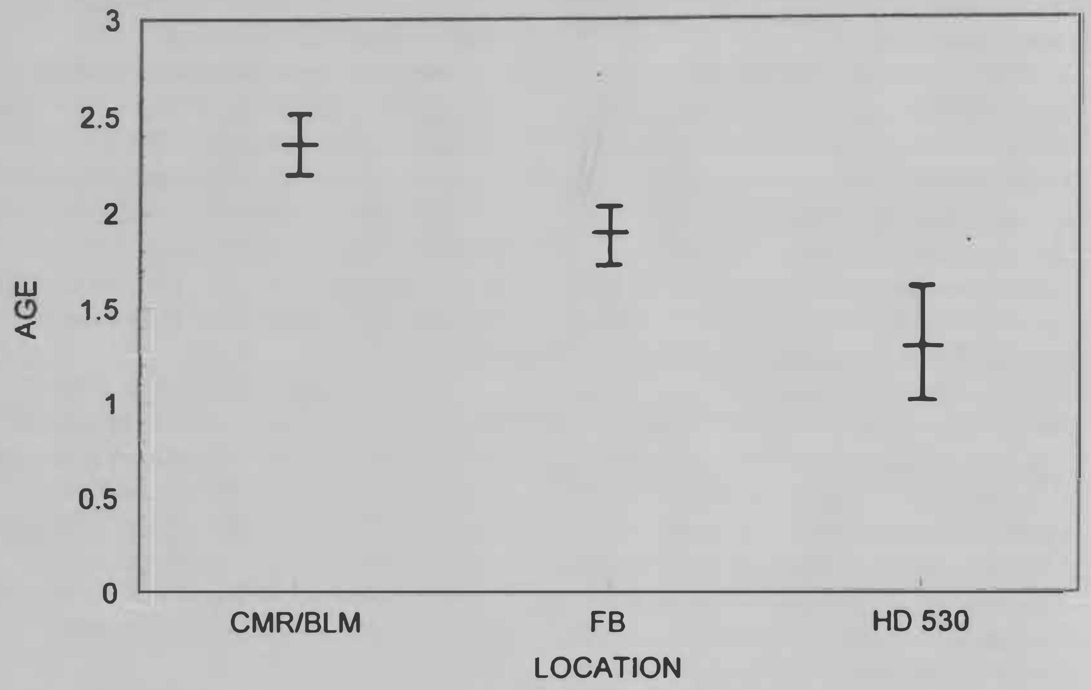

Figure 6. Mean ages of coyotes collected within CMR/BLM, FB, and HD 530 units, all years pooled.

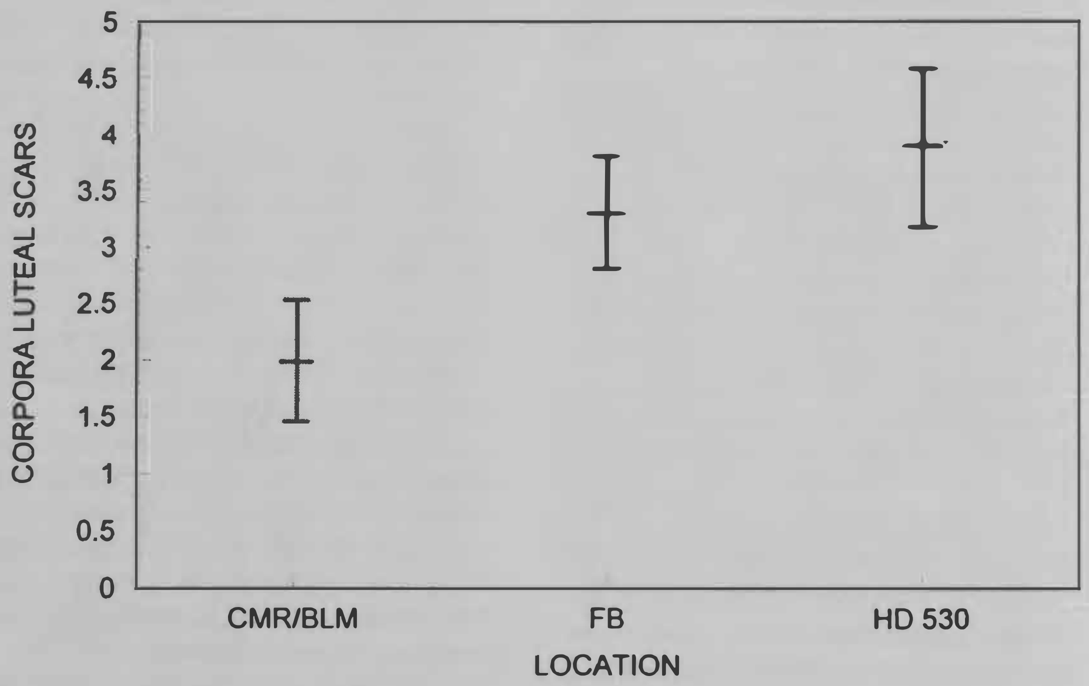

Figure 7. Mean number of CL produced by unit. All years of collection for individual units were pooled.

Discussion

Pyrah (1984) observed population densities of coyotes ranging from 0.15 to 0.26/km^2 in the Missouri River "breaks" of north-central Montana and lower densities of 0.07 to 0.20/km^2 in adjoining prairie habitats. The CMR/BLM and HD 530 units contained both "breaks" and prairie habitats (HD 530 breaks were associated with the Mussellshell River). The FB unit consisted primarily of prairie habitat interspersed with riparian areas and timbered buttes. Average daily helicopter harvest rates suggest densities were greatest on FB and the CMR/BLM, both of which had a harvest rate of more than twice that observed on HD 530.

Predator control conducted within these habitats yielded three different scenarios. The CMR/BLM was a large area (1620 km^2) with light coyote harvests (0.04/km^2) for two years then reduced to a small area (140 km^2) with more intensive control, averaging 90.5 coyotes (0.65/km^2) for the last two years. Initial coyote densities likely were high due to good habitat, abundant prey, and lack of prior control activities. FB was a large area (2460 km^2) initially sampled once a year with an average of 28.5 coyotes (0.01/km^2) collected/year. Predator control was intensified, conducted twice a year, and an average of 69 coyotes (0.03/km^2) were killed/year for the last two years. An effort was made to kill all coyotes during sampling sessions during the last two years of the study. Additional mortality occurred opportunistically by tribal members shooting coyotes from the ground. Populations appeared moderately high due to fair habitat, abundant prey, and limited control activities. HD 530 was a large area (2679 km^2) sampled intensively for three years, the harvest averaged 105 coyotes (0.04/km^2) per year. Although habitat was good and prey abundant, predator control activities prior to initiation of the study were more intensive than the other two areas, possibly resulting in a lower population density.

Comparisons among the three scenarios suggested that the CMR/BLM and its primarily "breaks" habitat was characterized by older coyotes that weighed less and were not as reproductively active as similar-age females observed in other units. The prairie-dominated FB unit produced coyotes of greater weight, younger age, and higher reproductive activity than the CMR/BLM. Reproductive rates exceeded those in the CMR/BLM but were lower, although not significantly, than those in HD 530. Coyotes in HD 530 that included a mixture of "breaks," prairie, and agriculture generally were younger but weighed more than coyotes in the other two units. Production of CL and number of breeding juveniles were highest in HD 530.

We observed little change in mean coyote age or sex ratio within each unit. Control activities did not significantly increase or decrease the age structure of harvested coyotes suggesting that population age structure within individual units did not change during the study. Mean weight of adult male coyotes varied over time for each study unit but apparently unrelated to control activities. Mean weight of adult female coyotes within individual units did not significantly change over the course of the study. Corpora lutea counts did not differ over time on either the CMR/BLM or FB units, and few juveniles bred successfully throughout the study. On the HD 530 unit, however, CL production increased significantly during the final year of the study, and the percentage of breeding juveniles increased over the three years of study.

Limited variation observed in age, weight, and reproduction within the CMR/BLM and FB, suggested relatively consistent environmental conditions and prey abundance for surviving coyotes. Control actions, limited due to size of the area (CMR/BLM) or intensity of kill (FB), were not sufficient to reduce competition for resources to a level that we would expect to influence reproduction within these units. Immigration likely helped replace coyote numbers within the study units and thus, maintained coyote densities.

In HD 530 harvested coyotes maintained relatively stable ages and weights throughout the study. CL counts and the number of breeding juveniles generally increased over the three years of study, but small sample sizes reduced our confidence in the results. Changes in prey abundance also could have contributed to an observed increase in CL production. Whether prey was more abundant because of favorable environmental conditions or decreased competition resulting from reduced coyote numbers was not determined. Assuming that environmental conditions remained stable, an increase in juvenile breeding activity and mean CL production may have directly resulted from intense coyote control and limited immigration.

Pyrah (1984) observed dispersal of both juvenile and adult coyotes. Juveniles dispersed greater distances and in greater numbers than adults (Pyrah 1984). Reduction in densities of the coyote population in the CMR/BLM and FB units may have stimulated emigration of what Pyrah (1984) described as adult den supernumeraries (from surrounding areas) resulting in fairly rapid replacement of the adult portion of the populations following control. Immigration likely occurred in HD 530, but given its large size and ongoing control activities in adjacent areas as the result of livestock depredation, movement into the study unit may have been limited.

Although many conditions can affect reproduction, others have demonstrated that abundance of food directly influences coyote productivity. Clark (1972) and Todd et al. (1981) observed a correlation of coyote density, percentage of breeding females, and litter size with prey density. Likewise, reducing coyote density through predator control led to increased densities or survivorship in prey species such as antelope (Smith et al. 1986, Willis et al. 1993, and Newell 2000) and some rodent species (Henke and Bryant 1999). Findings of these studies suggest that coyote reduction resulted in increased prey densities, which in turn should result in increased coyote reproduction. Initiation of coyote control programs could bring about a cycle in which increased coyote control would increase coyote reproduction until a physiological maximum is reached. Theoretically, an increase in coyote reproduction should be evident, provided control efforts successfully reduce coyote numbers to the point where competition for prey is impacted.

Removal efforts on the CMR/BLM and FB units probably were not effective in lowering coyote densities below that which could be compensated by immigration and normal levels of reproduction. Therefore, reproduction did not increase. The higher rate of reproduction in HD 530 suggested control efforts affected coyote densities that resulted in increased abundance of prey species for surviving and immigrating coyotes. Higher CL counts and a greater percentage of juvenile coyotes reproducing in that unit may be at least partially attributed to intensive coyote control.

Although predator control has occasionally been successful in decreasing losses of domestic livestock (U.S. Department of the Interior 1978, Wagner and Conover 1999), success of programs intended to increase survival of wild ungulates has been less certain. Studies done in Montana and elsewhere indicated a potential benefit for antelope and deer populations (Austin et al. 1974, Beasom 1974, Smith et al. 1986, Newell 2000). Electric fences (Matchett 1997) and lethal control (Vosburgh and Stoneberg 1998) were used in an effort to protect black-footed ferrets within the ferret recovery area in Montana. Despite continued coyote control, Montana coyote populations have persisted. Increased reproductive potential due to decreased coyote population density may have been one reason for the coyote's ability to maintain a population over a large area. However, based on the results of this study, reproduction only increased under intensive control. Limited control efforts may merely compensate for natural mortality.

To effectively increase survivorship of prey species, control efforts need to be intensive enough to reduce the coyote population below levels compensable by immigration and increases in reproduction. Coyote control conducted over small areas or of limited intensity should only be undertaken for programs that require a short window of predator control. Programs not aimed at coyote control but which require the killing of coyotes, such as disease monitoring, may be conducted on a limited scale without the concern of increasing overall coyote reproduction or greatly influencing age structure of the population.

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Morphology and Development of Gametophytes and Embryo in Unisexual and Anomalous Bisexual Flowers of Quaking Aspen

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Abstract

Several populations of dioecious quaking aspen *(Populus tremuloides* Michx.) and four trees with bisexual (perfect) flowers were studied. Flower development in all catkins was acropetal, initiated in winter buds, and completed prior to anthesis. Bisexual flowers were protandrous with one-five stamens. Anther wall development in both staminate, and bisexual flowers conformed to the Dicotyledonous type. The tapetum was of the secretory type and tapetal cells remained uninucleate throughout development. Microsporogenesis was simultaneous, forming tetrahedral tetrads. Pollen was spherical and of variable sizes of which 93 and 86 percent were fertile among staminate and bisexual flowers, respectively. Pollen was shed as single binucleate grains. In both pistillate and bisexual flowers, ovules were anatropous, female gametophyte development conformed to the Polygonum type, endosperm was nuclear, and embryo development was of the Asterad type. The innermost layer of the single integument was sclerified following fertilization, and the hairs associated with seeds were of funicular origin. In five percent of the bisexual flowers, the fertilized ovules either degenerated or were arrested at the zygote stage. In 10 percent of the flowers, only one ovule in the ovary developed while the remaining ovules degenerated. Other abnormalities in the bisexual flowers included degeneration of one to several stamens.

Key words: bisexual flowers, dioecious, embryology, funicular hair, gametophytes, morphology, *Populus tremuloides*, quaking aspen, Salicaceae.

Introduction

Quaking aspen (*Populus tremuloides* Michx.) is the most widely distributed native North American tree species of commercial and ecological importance (Jones 1985). Variation in form, growth rate, and wood properties as well as clonal habit and the occasional deviation from dioecism have been observed in this species (Einspahr and Winton 1976, Mc Donough 1985). Despite the spotty western distribution in the United States, in two of the Rocky Mountain states, Utah and Colorado, the 404,858 ha (one million ac) of aspen forest comprise more than 25 percent of all commercial forests (Jones 1985). In Montana the 103,239 ha (255,000 ac) of aspen are scattered among the middle-elevation conifer forests and at the lower forest boundaries. In addition to its natural abundance, aspen also is widely cultivated as an ornamental tree because of its foliage and greenish-white bark.

Quaking aspen, included in the Section *Leuce* of the family Salicaceae, exhibits significant phenotypic variation throughout its transcontinental distribution. Several authors have subdivided the species into four species and 13 varieties or forms (Barnes 1969, Beetle 1974). Since much of the total morphological variation within the whole complex may be found in various combinations within single locales, Little (1979) recognizes this taxon to be a single heterogeneous species without subspecific taxa.

Quaking aspen is a deciduous dioecious tree, 6-30 m tall, that may sexually reproduce by 10-20 years of age. Seeds have a short period of viability in which proper moisture and substratum are essential for successful germination (McDonough 1985). However, vegetative propagation through vigorous production of root suckers results in single clones that sometimes cover 40.48 ha (100 ac) or more (Grant 1993). All trees in a clone are pistillate or staminate. However, some perfect flowers mixed with staminate or pistillate flowers and trees with both staminate and pistillate flowers have occasionally been observed in some clones (Erlanson and Hermann 1927, Santamour 1956, Pauley and Mennel 1957, Lester 1963, Strain 1964, Schriener 1974).

Breakdown from dioecy in quaking aspen has generated considerable interest. Whereas a majority of previous studies have focused on description of deviations, some reports described their distribution within the tree and inflorescence. Clones, which alternate between staminate, and pistillate flowers in different years or show combinations of perfect, staminate and pistillate flowers within or between inflorescences on the same tree, also have been reported (Graham et al 1963, Einspahr and Winton 1976). According to Pauley and Mennel (1957) the staminate-pistillate ratio among clones in a given locality may vary considerably ranging from 1:1 to 3:1 or more. Einspahr and Winton (1976) suggested that selfing of bisexual aspen trees may become a useful breeding tool for tree improvement programs emphasizing height and diameter growth and such wood properties as specific gravity and fiber length. Lester (1963) suggested that establishment of distributional patterns within trees and/or within inflorescences could form a basis for speculation and further experimentation on possible genetic, physiological, or environmental influences affecting sex expression.

Although the literature is extensive on various ecological and physiological aspects of the genus *Populus*, embryological studies are far from adequate. Of 35 species, only some aspects of embryology and pollen morphology of a few species have been studied (Graf 1921, Erlanson and Herman 1927, Nagaraj 1952, Kimura 1952, 1955, Gramuglio 1962, Campo 1963, Fechner 1976, Zhu and Li 1989, Palacios-Chavez et al. 1990). No detailed embryological literature is available on dioecious quaking aspen and none exists on bisexual forms. Considering this inadequacy and the variability of deviations from dioecisim, the present study attempts to furnish more comprehensive information on morphology and embryology of quaking aspen in general and the bisexual aspens in particular. It involves several populations of dioecious quaking aspen from Montana, Colorado, Idaho, and Utah and four trees bearing catkins with bisexual flowers. These bisexual trees were discovered by the author among the transplants from naturally-propagated stands near Red Lodge, Montana.

Materials And Methods

The material used in the present study consisted of six cohorts that included materials harvested from wild as well as cultivated trees. Individual cohorts are listed below:

1. In spring 1985, 22 trees were transplanted from two wild populations found near Red Lodge, Montana to the west end of the Science building on the campus of Montana State University-Billings (MSU-B). Nineteen of these trees, all approximately 15 years old at the time of this study (14 pistillate, one staminate and four bearing catkins with all bisexual flowers), were used.

2. Six staminate trees (all about 10 years old) were originally obtained from a local nursery and grew at the north side of the science building on the campus of MSU-B.

3. Eight pistillate and eight staminate trees near Red Lodge, Montana; all of undetermined ages were taken from wild populations.

4. Two staminate and two pistillate

trees near Ashton, Idaho were all from wild populations of unknown age.

5. Six pistillate and four staminate cultivated trees near Fort Collins, Colorado were all of unknown age.

6. One staminate and one pistillate tree cultivated in Salt Lake City, Utah both were of unknown age.

I examined 100 catkins from each tree/year for eight consecutive years to determine if the tree was staminate, pistillate, or bore catkins with perfect flowers. Voucher specimens are deposited in the Montana State University-Billings (MSU-B) herbarium.

To determine pollen size, volume, and pollen viability, mature anthers from the staminate flowers of the male trees growing on campus and near Red Lodge, Montana, and from bisexual flowers were randomly collected, lightly crushed and soaked in 1 percent acetocarmine for 8-12 hours. I measured and scanned 2000 pollen grains from each sample to determine fertility. Those appearing dense and darkly stained were considered fertile (Sharma and Sharma 1980).

For embryological studies, 50 reproductive buds, 100 young, and 100 old catkins were collected from all trees in their native habitats or in cultivation at MSU-B campus and fixed in FAA (formalin: acetic acid: 50% ethanol, 1:1:8 v/v) for 24 hours and stored in 70 percent ethanol. Customary methods of dehydration, infiltration and paraffin embedding followed Johansen (1940). Sections 5-15 μm thick were cut and stained in Heidenhain's iron alum hematoxylin with eosin in clove oil as a counter stain and mounted in klearmount. Camera lucida drawings of the developmental stages were made. Fresh ovules and seeds were dissected and stained with cotton blue to study the ovule vasculature and the funicular hair. Bracts were examined from 100 randomly collected reproductive buds and 100 catkins from each tree of the sample growing on campus. I also measured 100 mature catkins from those same trees to obtain average catkin length.

RESULTS

Overview of Flowering Pattern and Morphology of Catkin

Seven of 22 transplanted trees flowered in March 1992 of which two produced catkins with all perfect flowers. Four trees produced all pistillate flowers, and one produced all staminate flowers. All 22 trees flowered in March 1993. The pattern of flowering for seven trees that flowered the previous year remained unchanged. Of the remaining 15, two produced all perfect flowers, and the other 13 produced only pistillate flowers. Three of the trees with all pistillate flowers did not survive to flower in 1994. The pattern of flowering in the remaining 19 trees has been consistent over the last eight years. Thirteen pistillate trees in this population grew between and near the bottom of two very shallow slopes. The four trees that bore catkins with all perfect flowers, one staminate tree, and one pistillate tree were slightly higher on the slope. Two of the trees that bore catkins with perfect flower appeared unhealthy after May 1998 and have produced 17 root suckers since. All other trees examined from Colorado, Idaho, Montana, and Utah were dioecious.

The 13 pistillate trees growing down the shallow slope were about 8 m tall; all others were 4-5 m. The short, straight trunks of all three types of trees bore irregularly bent limbs that made a narrow dome-like crown. The trees, with seemingly no differences in leaf morphology, produced petal-less flowers in catkins of variable length. Stamens and pistils were inserted on a saucer-shaped disc attached to the stalk by a short pedicel and subtended by a brown, hairy cleft bract. In all three types of flowers, development, which begins in the winter buds and is completed prior to anthesis in early spring, was acropetal.

Staminate catkins were 2-3 cm long (2.53±0.51) with 80-90 flowers/catkin. The seven different shaped brown hairy bracts were three- to six-lobed (3- to 4-lobed most common), randomly distributed in the catkin, each with lobes of variable number and length. Number of stamens ranged from six to 16 and had short filaments of equal length with bright red anthers (Plate 1, Figs. 1-3 and Plate 2, Fig. 5).

Pistillate catkins were 4-6 cm long (5.2 ± 1) with 100-120 flowers/catkin. The eight different shaped, randomly distributed brown hairy bracts were three- to eight-lobed (five to eight lobes were most common), each with lobes of variable number and length. Each flower showed two carpels and two bright red stigmas that were deeply cleft into two or more slender lobes (Plate 1, Fig. 4, Plate 2, Figs. 6-8). The fruits were 4-6 mm long with comose seeds.

Catkins bearing perfect flowers were 3-6 cm long (4.91 ± 0.84), each with 90-100 all perfect flowers. The five types of brown

Plate 1 Figs. 1-4. Photographs of flowers and bracts of quaking aspen (*Populus tremuloides* Michx.) from pistillate and staminate inflorescences. All figures X25.

Figure 1. Male flowers showing stamens and two types of bracts.

Figures 2-3. Male bracts.

Figure 4. Female flower with bract.

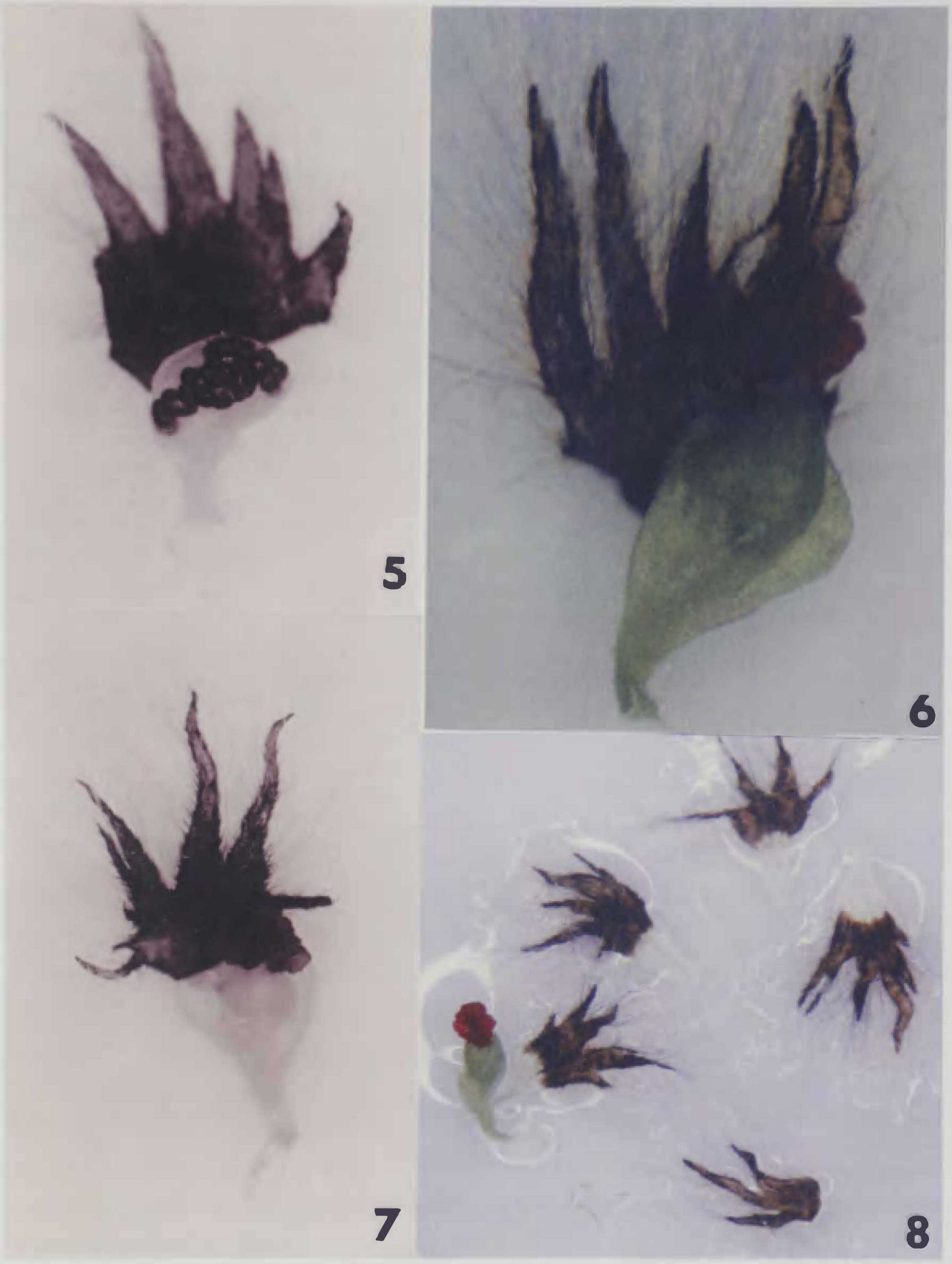

Plate 2 Figures 5-8. Photographs of flowers and bracts of quaking aspen (*Populus tremuloides* Michx.) from pistillate and staminate inflorescences.

Figure 5. Male flower with five-lobed bract X45.
Figure 6. Female flower with six-lobed bract X60.
Figure 7. Female flower with eight-lobed bract X45.
Figure 8. Female flower and three, four, five and six-lobed bracts X20.

hairy bracts of perfect flowers bore fewer lobes than those of unisexual flowers. These include four-lobed with two long and two short lobes (Plate 3, Fig. 9), wide and two lobed with one long and one short lobe (Plate 3, Fig. 10), narrow and two lobed (Plate 3, Fig. 11), narrow and entire (Plate 3, Fig. 12), and three lobed with the middle lobe longest (Plate 3, Fig. 13). The ones with three lobes were more frequent, and all types were distributed randomly in the catkin. The number of stamens ranged between 1-5 (Plate 3, Figs. 9-13, and Plate 4, Figs. 14-17), with two being most frequent (one on either side of the ovary). Several variations in the condition of the stamens were observed. The most frequently observed condition was flowers with two healthy stamens (Fig. 14). Several flowers showed two stamens, one healthy and one degenerated; in several others, three or more stamens were observed with one, two, three, or all degenerated ones (Plate 4, Figs. 15-17). In one percent of the catkins, flowers toward the apex had only one stamen, whereas in all other catkins flowers were randomly distributed. Filaments of all stamens were of equal length each with a bright red anther. The ovary was two-carpellate with a short stout style and two deeply cleft bright red stigmas. Fruits were 4-6 mm long and lance-ovate with comose seeds.

Microsporogenesis and Development of Male Gametophytes

Perfect flowers were protandrous. No significant differences were found in the development of the anther wall, microsporogenesis, and the male gametophyte between staminate and perfect flowers. Results for both types of flowers were therefore described together. Both staminate and perfect flowers showed anthers with four lobes. A plate of two to three archesporial cells developed in each lobe. Periclinal divisions in the archesporial cells resulted in an outer layer of primary parietal cells and an inner layer of primary sporogenous cells. The primary parietal cells divided periclinally to form secondary parietal cells. The innermost of these layers became the tapetum while the cells of the outer one divided to form one middle layer toward the tapetum and a layer of endothecial cells toward the epidermis (Plate 5, Fig. 18). The development of the anther wall, therefore corresponded to the Dicotyledonous type (Davis 1966). A young anther wall consisted of an epidermis, an endothecium, one middle layer, and the tapetum surrounding a massive sporogenous tissue (Plate 5, Fig. 18) The tapetum was of the secretory type, and its cells remained uninucleate throughout development. The endothecial cells enlarged considerably and developed bands of fibrillar thickenings at the time pollen grains were formed (Plate 5, Fig. 22). The tapetum and middle layer also began to degenerate about the same time. Primary sporogenous cells divided and enlarged considerably before they transformed into microsporocytes.

Meioisis was accompanied by simultaneous cytokinesis and the resulting microspore tetrads were tetrahedral. Each microspore developed a thick reticulate exine (Plate 5, Fig. 20). The pollen grains

Table 1. Variation in diameter ,volume, percent fertile and average size of pollen grains in quaking aspen (*Populus tremuloides* Michx.)

Diameter	Male	Bisexual
20µ - 23µ	4	7
24µ - 26µ	461	261
27µ - 29µ	1211	12
30µ - 34µ	271	97
35µ - 39µ	16	1421
40µ - 50µ	37	202
Total	**2000**	**2000**
Average	**28µ**	**40µ**
Volume	**820µ²**	**1675µ²**
% Fertile	**93**	**86**

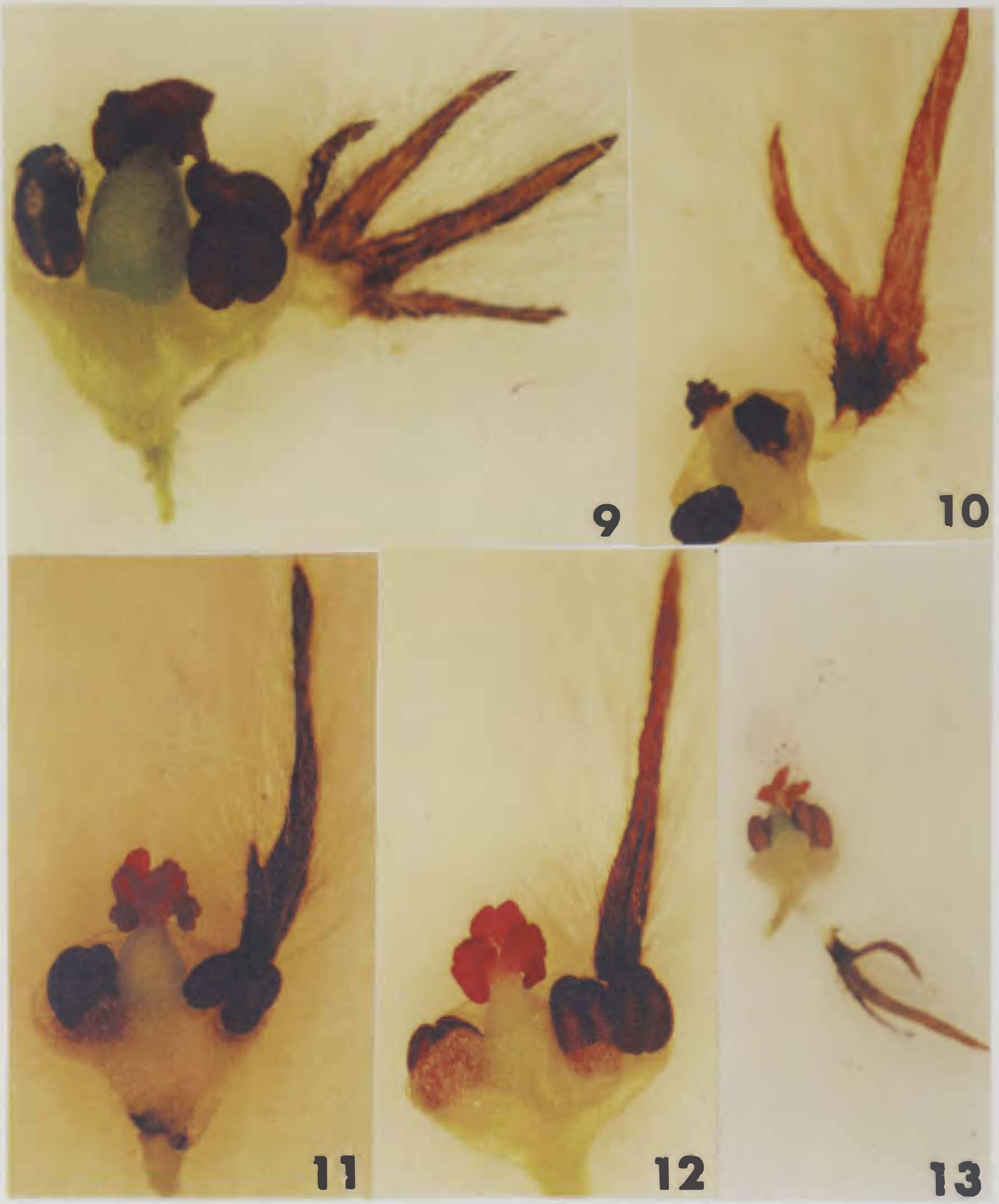

Plate 3 Figures 9-13. Photographs of bisexual flowers and bracts of quaking aspen (*Populus tremuloides* Michx.)

Figure 9. Bisexual flower showing pistil, two stamens (one of the anthers dehiscing) and four-lobed bract X50.

Figure 10. Bisexual flower showing pistil, two stamens (one degenerating) and two-lobed bract X30.

Figure 11. Bisexual flower showing pistil, two stamens and two-lobed bract X45.

Figure 12. Bisexual flower showing pistil, three stamens and unlobed bract X50.

Figure 13. Bisexual flower showing pistil, two stamens and three-lobed bract X15.

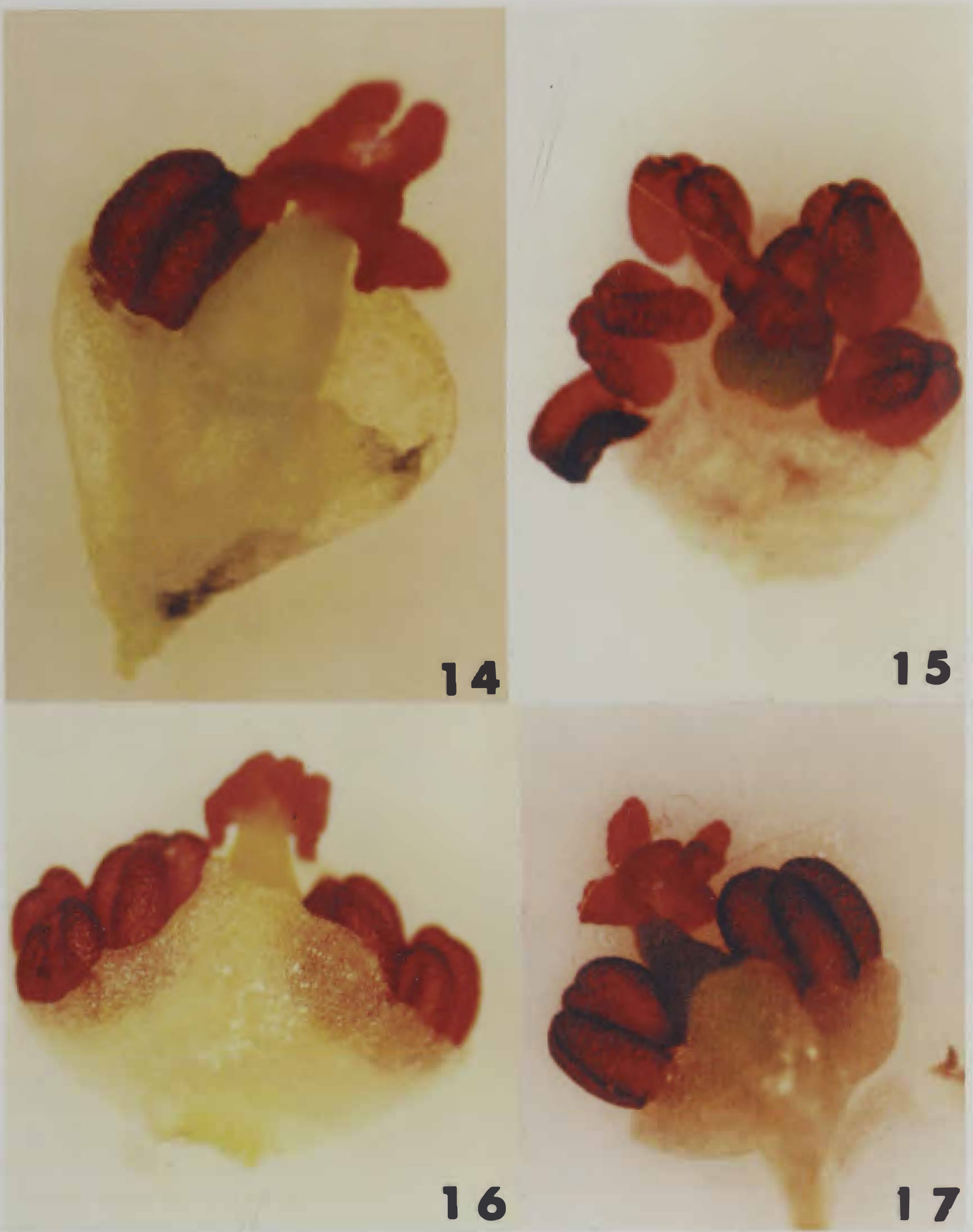

Plate 4 Figures 14-17. Photographs of bisexual flowers of quaking aspen (*Populus tremuloides* Michx.)

Figure 14. Bisexual flower showing pistil and one stamen X80.
Figure 15. Bisexual flower showing pistil and five stamens X80.
Figure 16. Bisexual flower showing pistil and four stamens X90.
Figure 17. Bisexual flower showing pistil and two stamens X65.

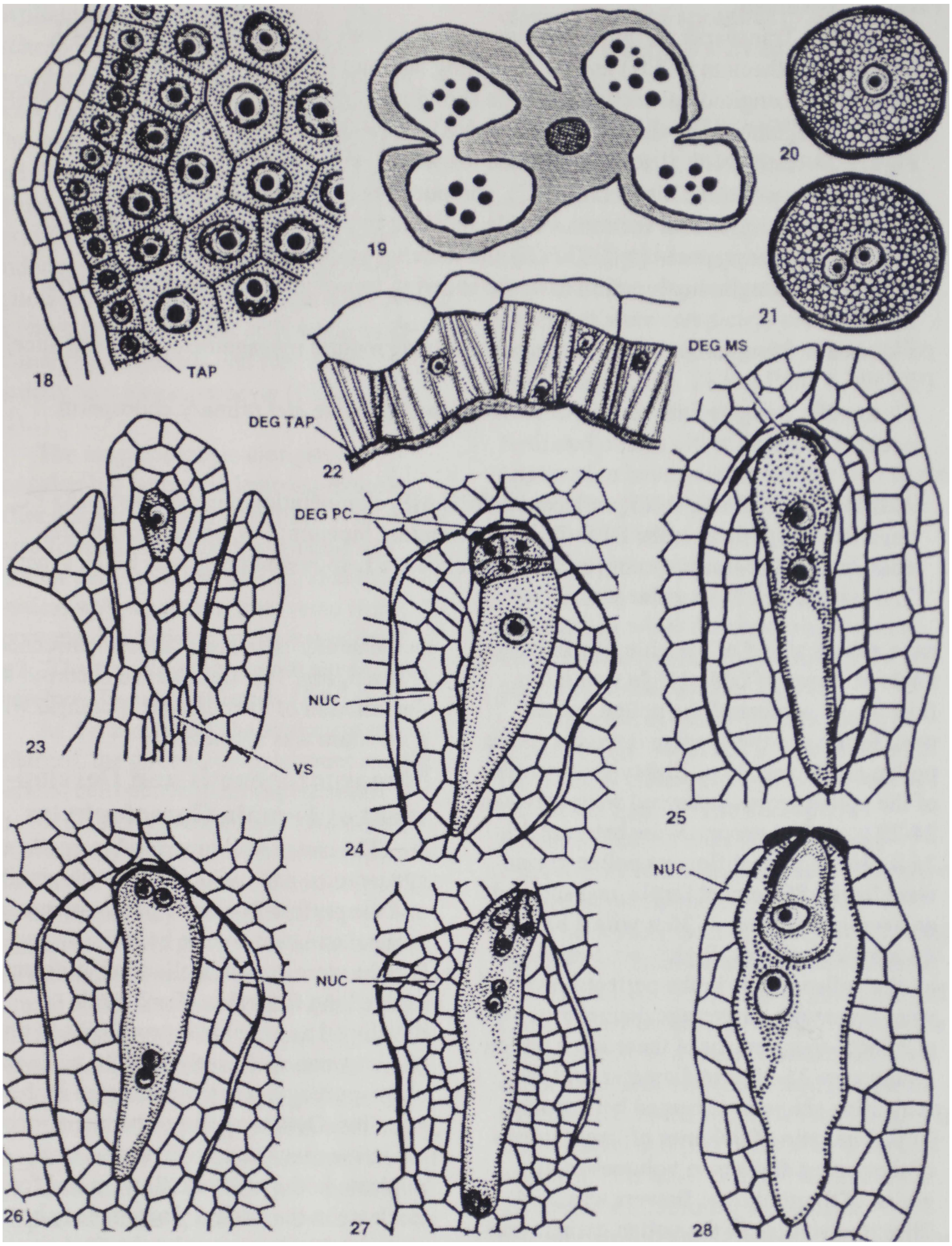

Plate 5 Figures 18-28. Microsporogenesis, development of male gametophyte (Figs. 18-22), megapsorogenesis and development of megagametophyte in bisexual quaking aspen (*Populus tremuloides* Michx.)

Figure 18. Transverse section of portion of anther showing epidermis, endothecium, single middle layer, tapetum and sporogenous tissue (= ST) . X2500.

Figure 19. Transverse section of mature anther showing coalescence of adjacent locules. X160.

Figure 20. Uninucleate pollen grain. X2500.

Figure 21. Two-nucleate pollen grain. X2500.

Plate 5, Continued.

Figure 22. Transverse section of portion of anther wall showing epidermis (= EP), fibrillar endothecium (= EN) and degenerating tapetum (= DEG TAP). X1000.

Figure 23. Longitudinal section of ovule showing megasporocyte (= MSC), parietal cells (= PC), integument and vascular strand (= VS). X1600.

Figure 24. Longitudinal section of ovule showing T-shaped megaspore tetrad, degenerating parietal cells (= DEG PC), and nucellus (= NUC). X1200.

Figure 25. Longitudinal section of ovule showing two-nucleate megagametophyte, degenerating megaspores (= DEG MS) and nucellar epidermis. X1200.

Figure 26. Longitudinal section of ovule showing four-nucleate megagametophyte, X1200.

Figure 27. Longitudinal section of ovule showing mature megagametophyte and nucellus X750.

Figure 28. Longitudinal section of ovule showing zygote and primary endosperm nucleus. X1200.

ABBREVIATIONS: ANT, antipodals; DEG MS, degenerating megaspores; DEG PC, degenerating parietal cells; DEG TAP, degenerating tapetum; EN, endothecium; EP, epidermis; MSC, megasporocyte; NUC, nucellus; ST, sporogenous tissue; SYN, synergids; TAP, tapetum; VS, vascular strand.

were spherical and of variable size in both kinds of flowers (Table 1). In staminate flowers, 93 percent of the pollen grains were fertile and the average diameter of the pollen grains was 28 μ. Eighty-four percent of the pollen grains measured were between 24-29 μ, and 14 percent were between 30-34 μ. In the perfect flowers pollen grains were larger, 86 percent fertile, and showed an average diameter of 36 μ with a bimodal distribution of sizes. Eighty-six percent of all the pollen grains in the perfect flowers were large with an average diameter of 38 μ. Ninety-four percent of these large pollen grains were 35-50 μ in diameter, and the remaining six percent ranged between 30-35 μ. The ratio of volumes of larger grains of the perfect flowers to volumes of all grains of the staminate flowers was 2.04. Thus, the volume of the pollen grains from the perfect flowers tended to be twice that of the volume of pollen grains from the staminate flowers. Fourteen percent of the grains that were small (20-29 μ), in the perfect flowers (mean diameter of 25 μ) also showed variation in size. Of the smaller ones 93.5 percent were 24-26 μ, 4 percent were 27-29 μ, and 2.5 percent were 20-23 μ. In both they were shed at the two-celled stage (Plate 5, Fig. 21). Adjacent sporangia in the anther coalesced before dehiscence (Plate 5, Fig. 19). Dehiscence occurred at the junction of the adjacent sporangia where a stomium was organized.

Megasporogenesis and Development of Female Gametophytes

The ovary was superior, bicarpellate, syncarpous, and unilocular in both pistillate and the perfect flowers. Placentation was parietal and each locule bore six ovules. Ovules were crassinucellar and unitegmic with a long funiculus. Each ovule developed as a globular protuberance on the placenta and was nearly straight when the megasporocyte was differentiated in the nucellus. Ovules appeared hemianatropous when the megagametophyte was two-nucleate in the pistillate flowers and four-nucleate in the perfect flowers; they became completely anatropous by the time an eight-nucleate megagametophyte formed. The integument was differentiated at about the same time as the archesporium in the nucellar dome. It was two-three cells thick and remained so throughout development. The single vascular strand stopped at the base of the nucellus (Plate 5, Fig. 23).

Megasporogensis and the development of megagametophyte was similar in both pistillate and the perfect flowers. The archesporium was single celled and hypodermal. It was recognizable by its dense cytoplasm and conspicuous nucleus. The archesporial cell enlarged considerably and divided periclinally to give rise to a primary parietal cell and a primary sporogenous cell. The primary parietal cell underwent one more periclinal division followed by anticlinal divisions and resulted in two layers of parietal cells whereas the primary sporogenous cell functioned directly as a megasporocyte (Plate 5, Fig. 23).

The megasporocyte elongated considerably before undergoing meiosis. After completion of the first division, dyads were formed. The upper dyad cell was smaller than the lower and divided by a vertical wall whereas a transverse wall accompanied division in the lower dyad cell. The resulting megaspore tetrad was, therefore, T-shaped (Plate 5, Fig. 24).

As the functional chalazal megaspore enlarged, the three micropylar ones and the parietal cells above them degenerated. By the time a two-nucleate megagametophyte was formed, cells of the nucellar epidermis also began to degenerate (Plate 5, Fig. 25). As the developing megagametophyte continued to enlarge toward the micropyle, the remaining nucellar cells on its either side formed a characteristic border simulating an inner integument (Plate 5, Figs. 26 and 27). These lateral nucellar cells persisted until the later stages of embryogeny (Plate 6, Figs. 29,30,36, and 38). Within each ovary, development of the megagametophytes was synchronous in all ovules. In 10 percent of the perfect flowers, only one ovule proceeded with further development while the remaining degenerated.

Mitotic divisions (Plate 5, Figs 25 and 26) in the functional megaspore resulted in an eight-nucleate megagametophyte (Plate 5, Figs. 27) and its development conformed to the Polygonum type (Maheshwari, 1950). A mature megagametophyte was eight-nucleate and consisted of an egg apparatus at the micropylar end, three antipodal cells at the chalazal end and two polar nuclei closer to the egg apparatus (Plate 5, Fig. 27). The synergids showed a filiform apparatus.

Fertilization, Development of Endosperm, Embryo and Seed

Before fertilization, the two polar nuclei fused to form a secondary nucleus and the antipodals degenerated. Fertilization was porogamous. Both synergids were completely crushed and degenerated during the entry of the pollen tube (Plate 5, Fig. 28 and Plate 6, Fig. 29). In five percent of the perfect flowers, fertilized ovules either degenerated or appeared to have been arrested at the zygote stage. The primary endosperm nucleus in those ovules had not undergone any divisions either. Occasionally, only one ovule in the ovary developed past fertilization while the remaining ovules degenerated. No such abnormalities were observed in the pistillate flowers.

Endosperm was of the Nuclear type (Plate 6, Figs. 30 and 31). The division of the primary endosperm nucleus preceded that of the zygote. The endosperm remained nuclear until later stages of embryogeny and eventually cell walls were formed between nuclei.

The development of embryo conformed to the Polygonum variation of the Asterad type (Johansen 1950). The zygote enlarged considerably before it divided. A transverse wall resulting in a short terminal cell (*ca*) and a long basal cell (*cb*) accompanied the first division of the zygote (Plate 6, Fig. 32). The terminal cell (*ca*) divided by a vertical wall while the basal cell (*cb*) divided by a transverse wall forming a T-shaped proembryonal tetrad (Plate 6, Fig. 33). The upper two tiers of the proembryonal tetrad were designated as (*ci*) and *m* (Plate 6, Fig. 33). The two juxtaposed cells formed by the division of the cell (*ca*) divided vertically in a plane perpendicular to the previous one and organized the quadrants *q* (Plate 6, Fig. 34). The middle cell *m* divided vertically and transverse divisions occurred in the cells of *q*. These divisions resulted in a four tiered embryo, *l*, *l'*, *m* and

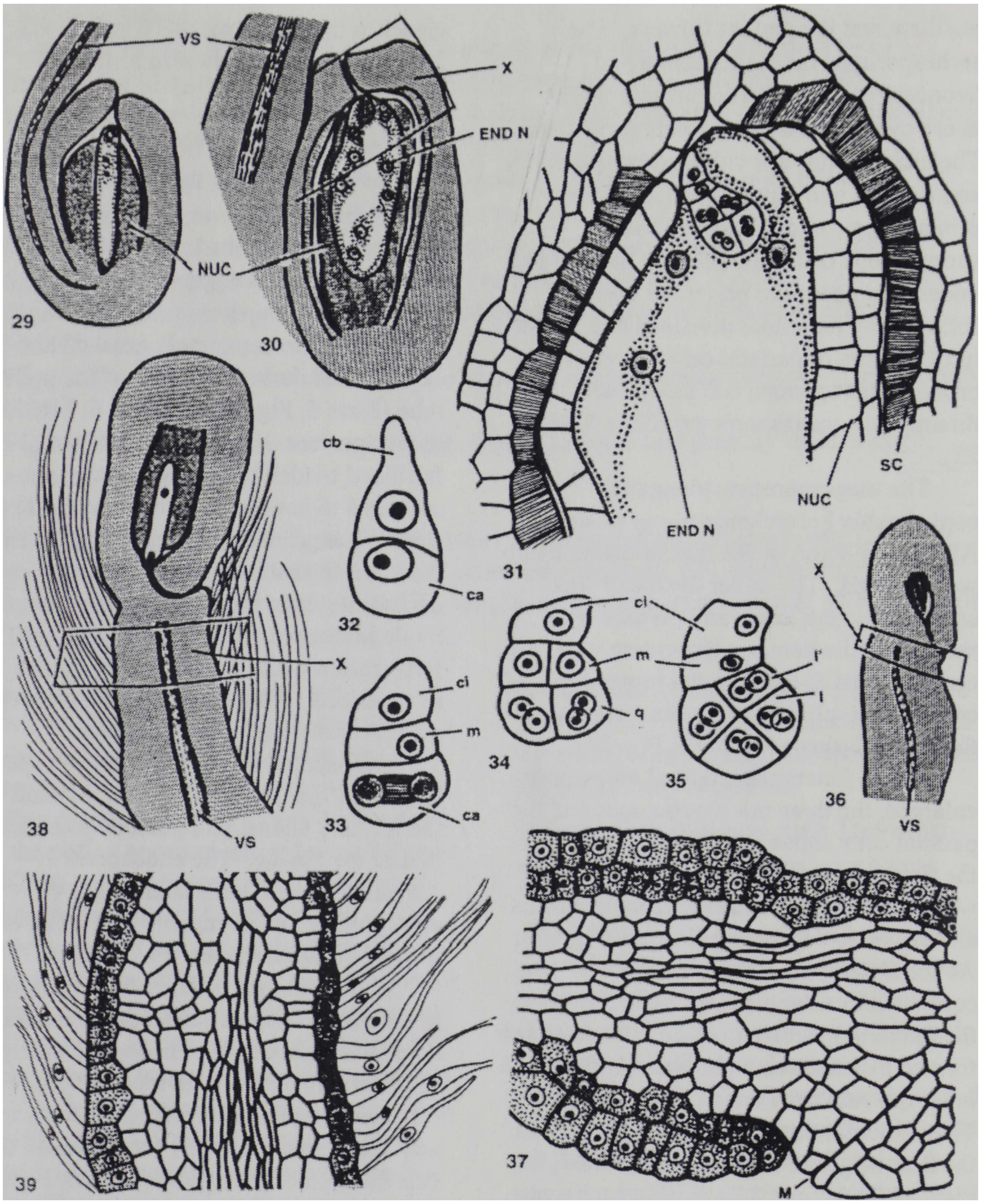

Plate 6 Figures. 29-39. Development of endosperm, embryo, funicular hair and seed coat in bisexual *Populus tremuloides* Michx.

Figure 29. Longitudinal section of ovule showing funiculus, vascular strand Nucellus (= NUC) and mature megagametophyte before fertilization. X300.

Figure 30. Longitudinal section of ovule showing eight-nucleate endosperm (= END N), embryo (= EMB), nucellus (= NUC) and sclerification of inner layer of integument. X300.

Figures 31. Portion marked "X" in Figure 30 enlarged. X1200.

Figure 32-35. Stages in the development of embryo. All X1500

Figure 36. Longitudinal section of ovule showing funiculus, vascular strand (= VS) nucellus and integument. X200.

Figure 37. Portion marked "X" in Figure 36 enlarged to show the initials of hair cells (= HI). X1000.

Plate 6, Continued.

Figure 38. Longitudinal section of ovule showing funiculus, vascular strand (= VS) nucellus, integument and hair cells. X300.

Figure 39. Portion marked "X" in Figure 38 enlarged to show the hair cells. X1000.

ABBREVIATIONS: ca, apical cell; cb, basal cell; ci, lower daughter cell of cb; EMB, embryo; ENDN, endosperm nuclei; HI, initials of hair cells; l, upper tier of octant; l', lower tier of octant; m, middle cell; M, Micropyle; NUC, nucellus; q, quadrant; SC, sclerified cells; VS, vascular strand.

ci (Plate 6, Fig. 35). The cell *m* after two vertical divisions formed four cells which together with the cells of the tier *l'* divided periclinally and formed dermatogen. Further divisions in the embryonic mass after the second periclinal division were irregular. The region l formed the stem tip, the tier *l* gave rise to a part of the hypocotyl while the remaining portion of the hypocotyl was derived from *m*.

Following fertilization, the epidermal and subepidermal cells of the funiculus enlarged showing conspicuous nuclei and dense cytoplasm (Plate 6, Figs. 36 and 37). The epidermal cells were transformed into hair cells and the subepidermal cells then became the outermost layer of the funiciulus (Plate 6, Figs. 38 and 39). The hair cells remained uninucleate and continued to elongate during embryo development and reached the tops of the ovules when the embryo was globular (Plate 6, Fig.38). The funicular hair cells eventually formed the tuft of coma on mature seeds. Simultaneous with these changes, the innermost layer of the integument began sclerification. By the time a proembryonal tetrad was formed, this layer was completely sclerified (Plate 6, Figs. 30 and 31).

Discussion

Erlanson and Hermann (1927) reported the first quaking aspen tree with perfect flowers. Santamour (1956), Pauley and Mennel (1957), Einspahr (1960), Lester (1963), and Maini and Coupland (1964) recorded subsequent combinations of hermaphroditism. Every and Wiens (1971) reported several trees from the Parleys Canyon population of aspens in Utah that were at first characterized as pistillate but on closer inspection were hermaphroditic and producing almost entirely perfect flowers. Deviations from dioeciousness include trees with both staminate and pistillate catkins; trees with catkins having both staminate and pistillate flowers; trees having catkins with some perfect flowers; and trees with various combinations of the above. Although several cases of hermaphroditism existed as defined above, a majority of those trees had flowers that were unisexual in initiation, development, and expression (Lester 1963).

The trees described in this study were different from those described by Erlanson and Hermann (1927) and others. All catkins that I examined from each of the four hermaphrodite trees for eight consecutive years contained only perfect flowers. To the contrary, Erlanson and Hermann (1927) observed perfect flowers in the center section of the catkin with fewer female flowers located distally; even fewer male flowers were found proximally. Although in one percent of the perfect catkins, flowers toward the apex of the catkin had only one stamen, no consistent pattern of an acropetal decrease in the number of stamens was observed in the present study unlike the previous report (Erlanson and Hermann, 1927). However, when compared to staminate flowers, the perfect flowers showed a lower average number of stamens/ flower. In 80 percent of the perfect flowers all stamens were normal and fertile. The most frequently observed condition was two healthy stamens, one on either side of the ovary. In 20 percent of the flowers, however, several combinations of normal and degenerating stamens were observed. Several flowers showed two stamens, one healthy and one degenerated; others showed ≥ 3 stamens with one, two, three or all degenerated. Erlanson and Hermann (1927) also reported variable number of stamens in the perfect flowers ranging from one to eight stamens, with three being most frequent. Although Erlanson and Hermann (1927) reported polyspory and other anomalies in microsporogenesis, they did not observe any degenerating stamens in the perfect flowers.

Santamour (1956) examined 67 wild quaking aspen and determined that three of 28 female and two of 39 male trees were hermaphroditic. However, he did not distinguish among trees having all perfect flowers, predominantly female with either male or perfect flowers, and predominantly male with either female or perfect flowers. Santamour (1956) also reported that in progeny of 131 trees from intraspecific crosses, 46.7 percent of the females and 1.4 percent of the males were hermaphroditic. The greatest number of trees were from intraspecific crosses utilizing a known hermaphrodite as the female parent. Of the progeny examined, 54.7 percent of female and 2.9 percent of male trees showed evidence of hermaphroditism. In a controlled cross between a known hermaphroditic quaking aspen and bigtooth aspen (*P. grandidentata)*, one of two female hybrids was hermaphroditic. Santamour (1956) concluded that the tendency to exhibit hermaphroditism may be inherited, and since the phenomenon was found primarily in female trees, perhaps the trait is X-linked; the self-fertile hermaphrodites may provide a tool for forest tree improvement.

In the present study, all dioecious trees consistently produced catkins with only unisexual flowers and the bisexual trees produced all perfect flowers over the eight consecutive years they were examined. Lester (1963) recorded varying degrees of perfectity and deviant flowers in 44.8 percent of the 138 trees he examined in two consecutive years. Deviations included perfect flowers, vestigial sex structures, and catkins with both staminate and pistillate flowers or with staminate, pistillate, and perfect flowers. For some trees the second-year sample revealed that many new deviants had arisen in trees that were unisexual the first year. He also corroborated earlier reports of an acropetal change from male to female character in the catkins. Lester (1963) concluded that hermaphrodites are not typically found in stands but in one or a few isolated trees and deviation from dioecism in quaking aspen is a phenomenon of considerable variability with an uncertain basis.

In addition to differences in the number of stamens and percentage of fertile pollen, the present study also revealed differences in the number and appearance of bracts in perfect flowers. Whereas male flowers showed three- to six-lobed bracts of seven different types, and female flowers were associated with three- to eight-lobed bracts of eight different types, the perfect flowers were subtended by one of five distinct types of brown hairy bracts. Linear, non-cleft and two- cleft bracts with one very small and the second long lobe were unique to perfect flowers. The three-, four-, and five-lobed bracts, although similar in the number of lobes, were morphologically distinct from those of the male and the female flowers. Likewise, bracts associated with male and female flowers were morphologically distinct and specific to each type of flower. Despite differences in the shape and number of lobes, no correlation occurred between a specific type of bract and its position on the catkin. There also was no correlation between a specific type of bract and the number of stamens in perfect flowers.

In this study microsporogenesis and anther wall development in both perfect and male flowers conformed to the Dicotyledonous type even though Davis (1966) reported a Monoctyledonous type of anther wall development for the family Salicaceae. The tapetal cells remained uninucleate through out development and only one middle layer was observed in anthers of both male and perfect flowers. agaraj (1952), however, reported binucleate tapetal cells and two-three middle layers in the anther wall of eastern cottonwood (*Populus deltoides)* . In this study both male and perfect flowers showed only tetrahedral tetrads unlike eastern cottonwood, where tetrahedral and isobilateral microspore tetrads were observed (Nagaraj 1952). Results of this study showed variation in size and fertility of pollen grains in both male and perfect flowers. The volume of pollen grains from perfect flowers tended to be twice the volume of the pollen grains from male flowers and suggested (at least as a first approximation) that perfect flowers may be tetraploid. The bimodal distribution of pollen diameters in the perfect flowers further emphasized that the four trees included one diploid and three tetraploids. Erlanson and Hermann (1927) also reported that pollen grains in the perfect flowers included several sizes ranging from dwarf spherical grains to exceptionally large grains; pollen of male flowers was markedly smaller and dwarf grains were rarely found. Every and Wiens (1971) reported pollen from several diploid trees to show a wide variation in size and a few cases exhibited a bimodal size distribution (30 μ and 50 μ). They considered the large size class (50 μ) to represent the unreduced (2n) pollen.

Megasporogenesis, development of female gametophyte, and ovule in both perfect and female flowers, conformed to other previously studied species of *Populus* (Nagaraj, 1952). However, in the present study, ovules appeared hemiantropous when the megagametophyte was two-nucleate in female flowers and four-nucleate in perfect flowers and became completely anatropous by the time an eight-nucleate megagametophyte was formed. Nagaraj (1952) observed a hemianatropous condition at the megasporocyte stage and a complete anatropous condition before the megagametophyte attained a two-nucleate stage in eastern cottonwood and quaking aspen. Fertilization and development of endosperm was similar in both female and perfect flowers and consistent with previous reports for *Salix* and *Populus* (Davis, 1966). Results of this study showed Polygonum variation of the Asterad type of development in both female and perfect flowers. Nagaraj (1952) reported an Onagrad type in eastern cottonwood, and although no details were given, he alluded to a similar development in quaking aspen as well. Zhu and Li (1989) described a Solanad type of embryogenesis in *P. lasiocarpa*. An Asterad type of embryogenesis has also been reported in *Salix* (Davis 1966).

The hair cells that eventually formed the tuft of coma on mature seeds were funicular in origin in both female and perfect flowers in this study. These observations were consistent with tho e of Fechner (1976) for female flowers of quaking aspen. agaraj (1952), however, reported hair of placental origin in both in eastern cottonwood and quaking aspen.

The present study revealed some striking abnormalities in perfect flowers that point to their polyploid nature. In five percent of these flowers, the fertilized ovules either degenerated or apparently had been arrested at the zygote stage. The primary endosperm nucleus in those ovules had not undergone any divisions either. In 10 percent of the flowers, only one ovule in the ovary had developed whereas the remaining ovules had degenerated. These abnormalities, when combined with the pattern of degeneration of stamens, relatively lower number of stamens, and lower pollen fertility were significant in light of suggestions made by several authors (Santamour 1956, Lester 1963, Einspahr and Winton 1976) regarding use of bisexual aspens in breeding programs for forest tree improvement.

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Abstracts

Biological Sciences - Aquatic

Effect of Rotenone on Diatom Viability [MAS]

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Diatoms play an important role in stream ecology, but their viability may be compromised by rotenone. Rotenone is a compound used by government agencies to control unwanted fish. I am using a diatom as a model organism to predict the impact of rotenone on stream ecology. I have devised a way to measure the effects of this compound on diatoms, which, if negative, have the potential to affect the entire ecosystem. Two methods were employed for this purpose. Motility has been shown to be a good indicator of cell health, so this was examined first. Cells were grown in a defined medium and prepared in a cell suspension. This suspension was divided, treated with rotenone for tests, left untreated for controls, and dispensed into test tubes. Cells were videotaped on a microscope slide at one, four, and twenty-four hour intervals to calculate percent motility. A reduction in percent motility compared to healthy cells indicated an effect of the rotenone. The second method employed was an adhesion assay. It has been shown that diatoms contribute to sediment stability, which requires adhesion. To measure the percent adhesion, a cell suspension of 400,000 cells was placed in a beaker containing a cover glass. Triplicates are made of each test and control. The number of diatoms attaching to the cover glass is measured by determination of chlorophyl a and the results presented as a percent of the control.

Biological Sciences - Botany

Do Strip Bark Conifers Reflect $C0_2$ Fertilization in the 20th Century? [MAS]

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Mountain Research Center

I propose to investigate the potential for $C0_2$ fertilization of high elevation conifers in the Tobacco Root Mountains. At upper tree-line, it has been traditionally thought that tree growth is governed by growing season temperature. However, in the past several decades new research evidence has demonstrated unprecedented growth rates in upper tree line forest that have been ascribed to enhanced $C0_2$ fertilization. Strip bark trees in particular show this accelerated growth rate. Trees with the strip bark morphology are characterized by their

Title footnote indicates organization, location and date presentation was made:
[MAS]Montana Academy of Sciences Annual Meeting, Bozeman, MT, April 20-21, 2001
[TWS]Montana Chapter of the Wildlife Society Annual Meeting, Butte, MT, Feb. 28-March 2, 2001

partial cambial dieback, which may be directly related to their rapid growth rates. There remains a controversy pertaining to the geographical extent of this phenomenon and its physiological interpretation. The objectives of my research were to: Determine if white bark pine trees at upper tree line in the Tobacco Root Mountains exhibit anomalous growth rates during the 20th century. Assess the evidence for $C0_2$ fertilization as a cause of differential growth rates. My results will speak to the issue of whether increased atmospheric $C0_2$ concentrations during the 20th century has significantly altered tree growth, and thus serves as one of the first indications of the impacts of global change on terrestrial ecosystems.

BIOLOGICAL SCIENCES - TERRESTRIAL

QUANTITATIVE MOTION ANALYSIS AND SPATIAL DYNAMICS OF SNOWSHOE HARES IN DIFFERENT HABITAT TYPES [TWS]

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Snowshoe hares (*Lepus americanus*) are the primary prey of a threatened carnivore—the Canada lynx (*Lynx Canadensis*). A pressing management question in lynx conservation is how snowshoe hares respond to the pre-commercial thinning occurring across the northern U.S. I studied this habitat issue using quantitative motion analysis. Primary movement data provides a window into an animal's relationship with its landscape, and its behavior with detail. During winters from 1999-2001, I back-tracked radio-collared hares across snow on four forest thinning treatments in Northwestern Montana. I measured turning angles every 5 m for up to 70 m of path, distance and direction to shelter at each point, described habitat conditions and noted the behavior of the hare as evidenced by the tracks. I quantified the tortuosity (lack of directional bias) of hare paths in each of the forest treatment types. I also elicited realistic predator-avoidance behavior using a domestic dog to flush the hares. Baseline data indicate that hares in areas with high secondary growth exhibit higher tortuosity compared to the relatively "straight line" movements of hares in open areas. Interestingly, hares in open canopy young forest regularly move like hares flushed by a predator in closed cover. Thus, movements may reflect fitness consequences.

WINTER, SUMMER, DIURNAL, AND NOCTURNAL HOME RANGES OF SNOWSHOE HARES IN WESTERN MONTANA [TWS]

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Snowshoe hare (*Lepus americanus*) home range is an important parameter in mark-recapture density estimation, and could affect interactions between hares and the Canada lynx (*Lynx canadensis*). We estimated winter and summer snowshoe hare home range size in

Western Montana. We relocated adult radio-collared hares in winter (n = 6) and summer (n = 11) at all hours, and estimated home range area using a fixed kernel estimator. Male home range area in summer was larger than winter home range, while female summer home range was comparable to winter home range. Estimated hare utilization distributions (u.d) in summer were larger than reported in previous studies; mean summer 95 percent u.d. home range was 23.9 ha for males and 10.7 for females. Three female and four male hares had estimated 95 percent u.d. home ranges larger than 13 ha in summer. Average summer daytime 75 percent u.d. home range size was 3.31 ha smaller across all hares than summer nighttime home range. In the summer, females appeared to have a larger nocturnal home range relative to their total home range than did males. Hares with core areas of their home ranges within mature forest stands with complex vegetation structure generally had larger overall home ranges.

Update on Mountain Lion Research in the Garnet Mountains [TWS]

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Mountain lion research began in the Garnet Mountains in 1998 to better understand characteristics of a hunted lion population and evaluate the accuracy of track surveys and other techniques to monitor trends in lion abundance. The 330 square mile study area located south of Ovando represents typical hunted mountain lion habitat of central and western Montana. Fifty-one mountain lions have been equipped with transmitters and research to date indicates that lion biology and ecology are similar to other studied lion populations. Hunting resulted in 14 of 21 radioed adult lions harvested during 1998 and 1999. Lion hunting was suspended for 3 years starting in 2000 in order to capture all lions in the study area and to allow the population to increase. After a 3-year increase, hunting will again be allowed, thus reducing the number of lions. By having the population increase and then decrease we can determine which population indicators are most sensitive to changes in lion abundance. Population indicators being evaluated include trends in the number of lion tracks on survey routes. Eleven routes (7-39 miles in length) have been established and were searched primarily by snowmobile 10 times this winter to document the number and location of lion tracks. These 170 miles of roads and trails will be inventoried during the 6-year period to determine the relationship between lion track density and the actual density of lions. Other population indicators being evaluated include lion observations by deer hunters sampled through FWP's statewide telephone survey; interviewing a portion of the state's houndsmen to record views on lion trends; lion hunting statistics; deer and elk trends in the study area; and lion DNA sampling.

Detecting Canada Lynx in Glacier National Park, Montana [TWS]

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Historic records of Canada lynx (*Lynx canadensis*) sightings and tracks in Glacier

National Park were summarized in 1994. A pilot snow-track survey for forest carnivores was also begun in 1994, and winter track surveys have been repeated annually since then, supplemented with a few remote camera stations. These surveys and anecdotal reports provided useful information on the distribution of lynx in the park, but little information on the status of the lynx population. Initial efforts to apply emerging detection techniques using DNA analysis of hair samples were undertaken during the late summer of 1999. A 100 mi^2 (259 km^2) area in the North Fork drainage, 86 percent in the park, was sampled using the protocol developed by John Weaver. No lynx were detected during this survey of a remote area with few previous lynx track records. During summer/fall 2000, we tested the USFS National Lynx Detection Protocol (NLDP) (KcKelvey et al. 1999) to 1) determine its effectiveness in the variety of habitats and topography that characterize the park, 2) assess the feasibility of conducting surveys with dense sympatric populations of grizzly bears and black bears, 3) obtain a minimum population estimate and additional information on lynx distribution, and 4) compare the systematic positioning of transects to a subjective approach to detection station placement. Using the NLDP, we established 87 transects with 433 stations in 3 study areas in Glacier National Park. This sampling effort yielded 76 hair samples: 8 lynx, 2 bobcat, 3 grizzly bear, 47 black bear, and other samples not yet identified to species. Five of the 6 lynx samples analyzed to individual to date were unique individuals. All lynx were detected in mixed conifer-aspen-meadow and treeline habitats; none were detected in the continuous coniferous forest habitats sampled. Twenty-nine percent of stations were disturbed (primarily by wind, bears, and/or elk), and at 13 percent of stations the visual lure was removed by the end of the sampling period. Twenty transects with 100 stations were placed subjectively in areas sampled with the NLDP. Three hair samples were collected from these stations, of which 2 were lynx – a comparable rate per station to the NLDP. These methods were successful in detecting lynx in areas where they were known to occur.

Understanding Relationships Betwee Sage-Grouse Habitat and Population Dynamics in Eastern Montana [TWS]

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The long-term decline of greater sage grouse (*Centrocercus urophasianus*) over much of their historic range is of concern to managers of sagebrush (*Artemisia* spp) habitats. A petition has been submitted to list the Washington population of sage grouse under the Endangered Species Act (ESA) and a range-wide listing petition is expected in the near future. That habitat quality is related to demographics of populations is a fundamental assumption of the practice of managing species via managing habitat. However, few studies explicitly acknowledge this relationship, and still fewer explicitly attempt to define this relationship on a species-specific basis. There currently is no way to reliably determine the nature of the interaction between sage grouse population status (as indicated by estimated vital rates) and habitat condition. This research will use a combination of well-established population demography tools and state-of-the-art analysis methods to elucidate relationships between Sage-Grouse populations and habitat at 6 sites in eastern Montana. Mark-resight and radio telemetry methods will be employed to estimate vital rates of Sage-Grouse populations. Sensitivity analysis will identify which rate(s) has the greatest influence on population growth rate under different habitat conditions. Habitat condition at each site will be assessed by several crucial habitat characteristics. A regression approach will quantify the relationship between individual vital rates and each of the measured habitat characteristics. The research will provide crucial information to federal and state wildlife professionals charged with managing for sage grouse and will be of particular use in the event of a petition to list sage grouse under the ESA.

Evaluating Effective Group Release Size, Population Growth, and Survival Rate of Translocated Black-tailed Prairie Dogs on the Charles M. Russell National Wildlife Refuge, Montana TWS

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Black-tailed prairie dogs (*Cynomys ludovicianus*) are an integral component of prairie ecosystems, but in recent years their numbers have been reduced due to eradication programs, conversion of grassland to cropland, and the spread of sylvatic plague. In an effort to re-establish prairie dogs into plagued historic colony sites, translocation efforts began in 1997 on the Charles M. Russell National Wildlife Refuge (CMRNWR). Translocation experiments require several issues be determined: 1) Conditions needed for successful translocation such as stocking density; 2) Survival of translocated animals; and 3) Colony size. Stocking density was addressed by comparing group release sizes of 120 animals, 60 animals, and no animals (control) on three different size classes of remnant colonies, >5, 0.1-5, and 0 acres. Survival rates of translocated animals were ascertained using mark-recapture techniques. The numbers of translocated animals within the release area were calculated using visual counts, live-trapping techniques, and burrow densities. Prior to this study, the perimeters and burrow densities of each colony on the CMRNWR were mapped with a Global Positioning System and used as baseline data. Monitoring colony sizes and burrow densities provided important information necessary for determining changes due to recolonization, augmented and natural. From the information gathered, I determined the affects of augmentation.

Estimating Green Biomass of Big Sagebrush using Remote Sensing Techniques: Preliminary Results [TWS]

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An efficient method to estimate amounts of Big Sagebrush (*Artemisia tridentata*) would be helpful for assessing habitat for a wide range of species and determining change over time. Preliminary results from our work in sagebrush/grassland habitats of Yellowstone National Park and the Missouri Breaks indicate light reflectance from a portable radiometer can predict green biomass of big sagebrush (*Artemisia tridentata*) in addition to biomass of herbaceous vegetation. During 1999 and 2000, we took radiometer readings and dimension measurements of sagebrush plants in 0.75 m diameter plots prior to collecting all green portions of sagebrush plants. Individual bands of reflected light predicted green biomass ($R^2 = 0.68$) of sagebrush in 48 plots known to contain sagebrush. In itself, sampling with a portable radiometer could be used to quickly estimate green sage biomass over large areas. We are currently trying to apply our results to estimate sage biomass on a landscape scale using satellite imagery.

Nesting Habitat Selection and Productivity of Northern Goshawks in West-central Montana [TWS]

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During the 1997 and 1998 nesting periods, I systematically surveyed for Northern Goshawks (*Accipiter gentilis*) using a randomized design across all available forest cover types in the northern Flint Creek Range in west-central Montana. The study was done to obtain an unbiased estimate of nest-site selection, quantify nesting habitat at five spatial scales (landscape, post-fledging family area, nest stand, nest-tree area, and nest tree proper), and compare the success and productivity of goshawk nesting attempts among habitats selected by goshawks. Results suggested that in an intensively managed landscape, goshawks selected a core area of mature forest (15 ± 3.6 ha) that was surrounded by denser, smaller-sized trees. Logistic regression predicted goshawk presence based on the proportion of land within the post-fleding family area that contained north aspects, high canopy closure, and fewer clear-cut harvest areas. At the nest-stand scale, discriminant function analysis (DFA) separated occupied nest stands ($n = 19$) from random ($n = 30$) based on greater canopy closure, shrub cover, large-sized tree density, and less wood litter; at the nest-tree area, greater total plant cover, canopy closure, large tree density, and less sapling density; and at the nest-tree, greater diameter at breast height and height to the lowest live limb. I also evaluated specific landscape and physiographic features associated with nests, and DFA separated occupied from random sites based on less distance from the nest to a forest opening, less distance from the nest to the edge of the nest stand, and lower elevations. Occupied nest sites were dependent on aspect with 82.6 percent located on north slopes. The number of young fledged per nest was negatively correlated with the size of the forest opening near the nest and sapling densities in nest stands, and was positively correlated with the density of large-sized trees in nest-tree areas. I suggest that well-designed management treatments that maintain large areas of mature forest and focus on reducing small-sized tree densities in the understory should be able to improve existing conditions for goshawks.

Distribution of Forest Carnivores in the Pioneer Mountains, Montana [TWS]

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This project was initiated in the winter of 2000-2001 by the Rocky Mountain Research Station in cooperation with the Western Federal Lands Highway Division (WFLHD) of the Federal Highway Administration. Survey efforts are directed at meeting 2 primary objectives; 1.) Determine the distribution of lynx and other forest carnivores in the Pioneer Mountain Range, and 2.) Determine the location and relative frequency that lynx and other wildlife (forest carnivores, elk, deer, mountain lions, coyotes, and bobcats) cross the Polaris Road. To address the first objective we overlaid suitable habitat within the mountain range with an 8-km grid in order to systematically and quantifiably conduct the large scale surveys. The approach is to cover a minimum of 10 km of survey route within each 8-km pixel. To address the 2nd objective we surveyed the closed portion of the Polaris Road a minimum of 1 time per 10 days. Surveys are conducted only between 48 and 72 hours after significant snowfall. All track data is GPSed and stored in a GIS upon return from the field. Between 1 January 2001 and 20 Februrary 2001a total of 764 km of GPS logged survey have been conducted in the 8-km pixels. Mammalian carnivore track crossings and data pertaining to habitat and prey species are recorded along these routes. In addition to the intensive surveys, approximately 4000 km has been covered in which observers record locations of lynx, wolverine, fisher, and wolves. To date we have not summarized all location data. Wolverine tracks have been detected on 8 survey routes across the mountain range. Wolf tracks have been documented on 2 entries of the same survey route. Martens are commonly encountered within certain habitat types. No lynx or fisher tracks have been documented at this time. We have surveyed the closed portion of the Polaris Road 4 times to date. Martens and coyotes are the most common carnivores using the road. Martens do not appear to travel along the road itself but simply cross. Coyotes are found crossing the road and using it as a travel corridor. Wolverine crossings have been documented on 2 of the 4 surveys. No lynx, fisher or wolf tracks have been detected to date.

Swan Valley Grizzly Bear Conservation Agreement: A Mixed Ownership Landscape Plan [TWS]

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A Conservation Agreement was developed and implemented in 1995 covering approximately 368,000 acres in the Swan Valley of west central Montana between Plum Creek Timber Company, Montana Department of Natural Resources and Conservation, U.S. Forest Service, and the U.S. Fish and Wildlife Service. This management plan allows the cooperators to meet economic and recreational objectives for their ownership while providing conservation benefits to grizzly bears using information from local scientific studies and the newest technology. The biological objective is to maintain landscape conditions conducive to grizzly bears to facilitate their movement between the Bob Marshall and Mission Mountains Wildernesses. Measures have been developed that minimize disturbance to bear habitat and the period of their likely use and to decrease the potential for human-caused mortality. Conservation measures include establishing linkage zones across the valley floor, the stepped rotation of commercial activities through the valley, landscape habitat and access management, and site-specific habitat prescriptions for forest management. Specific plan measures include the curtailment of management activities within linkage zones during the early spring period as bears emerge from dens; coordinating the commercial activity among landowners to occur in only 4 of 11 subunits during the non-denning period; retention of cover at both the landscape and stand level; and reducing public vehicular access in bear habitats by instituting road restrictions and road reclamations. The Plan includes monitoring such as evaluating the effectiveness of road closure devices, sampling administrative use levels within inactive subunits, tracking commercial activity, and reporting landscape cover levels.

Effects of Ponderosa Pine Restoration on Wildlife [TWS]

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Fire suppression in the last century has resulted in major changes in forest structure and process. The National Fire / Fire Surrogate Study is a nation-wide interdisciplinary project designed to assess impacts of restoring forest structure and/or process through the use of silvicultural tools and prescribed fire. Lubrecht Experimental Forest is one of 10 sites in the

study. A team of silviculturalists, soil scientists, entomologists, and wildlife biologists work together to provide insight into the broad impacts of forest restoration. I will be focusing on the effects of the silvicultural manipulations on wildlife. Specifically, I will examine the use and selection of beetle-killed trees by bark gleaners and try to assess how the removal of these trees may affect both food availability and foraging behavior. I will also examine the change in relative densities of small mammals as a result of the silvicultural treatment. I will focus on yellow pine chipmunks and deer mice, both abundant on the sites and both songbird nest predators and large mammal/ large bird prey. Determining theses responses will provide insight into different levels of forest responses, thereby providing valuable information to managers implementing these treatments.

What we can (and Cannot) Say About Wildlife Populations Using Non-Invasive Genetic Sampling TWS

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Non-invasive genetic sampling is emerging as a sexy new tool in the arsenal of techniques used by wildlife biologists. Like any new approach, it has promise, as well as pitfalls. I will discuss some genetic-based approaches that I am using, along with my students and other colleagues, to answer applied wildlife ecology questions. For example, abundance of elusive carnivores can be estimated using mark-recapture approaches coupled with non-invasive DNA sampling (such as hair snags), but there is a "shadow effect" that can arise from the failure to distinguish individuals based on unique genotypes. Species identification is also possible using non-invasive sampling, and we have developed diagnostic tests for distinguishing among felids (including lynx), dogs (including coyotes), bears, and mustelids (including wolverines, fisher, and marten) across the northern U.S.; these diagnostic tests are being incorporated into Nationwide sampling of lynx in collaboration with the USFS Rocky Mountain Research Station. Finally, genetic tools can be used to evaluate gene flow, as we have done with both lynx and small mammals. I will stress that genetic tools are valuable, but should not be used without validation; furthermore, the most productive avenue is to combine genetic and demographic (eg mark-recapture) approaches.

Gaining New Insights into Canada Lynx Management using DNA TWS

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Genetic data can be used to shed new light on old problems. We used genetic data on the Canada lynx (*Lynx canadensis*) to address questions concerning connectivity between lynx populations. Specifically, we tested if southern lynx populations are maintained by migrants moving from Canada to the United States or if southern lynx populations are selfsustaining, isolated entities. To address this question we analyzed lynx DNA with nine microsatellite markers and used the data to estimate gene flow between seventeen lynx populations in Canada, Alaska, and the contiguous United States. Our data shows that gene flow is extremely high between most lynx populations. We discuss this finding in light of the Evolutionary Significant Unit (ESU) concept. Furthermore, we emphasize that if lynx populations in the contiguous United States are maintained by gene flow, as our data suggests, then efforts must be initiated to ensure that movement to and from Canada is maintained or enhanced.

Hair Snaring and DNA Identification TWS

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In 1999 we developed and implemented a nationwide survey for lynx based on DNA identification of hair. In 1999 over 6000 hair snares were placed in 40 National Forests, and 1 National Park. In 2000 we expanded efforts to 44 National Forests, 3 National Parks, and the Salish-Kootenai Nation; over 7500 hair snares. We tested the efficacy of baited hair-snares, developed DNA primers to separate felids, ursids, canids, and mustelids and designed a protocol that could be implemented consistently by Forest Service employees and contractors across the US. Hair snaring proved effective for surveying lynx. In Kulane N.P., Yukon, a mixture of beavor castorium and catnip oil was twice as effective as 4 other lures tested. Lynx hair was found on 39 percent of the snares baited with this lure. For species-level identification, published mitochondrial DNA primers proved unreliable for amplifying DNA from hair samples. We therefore developed primers that amplified shorter sequences within the D-loop region of the cytochrome b gene, allowing positive identification of felids from very small samples. Surveys were designed to representatively sample relatively large areas while maintaining high probabilities of detection, and four "test" areas with known lynx populations were included to estimate probabilities of detection. In the first year, we obtained over 600 hair samples from the initial survey. While the 2000 samples have not been fully analyzed, we have documented lynx occurrence on 2 areas in northern Washington, in the Seeley Lake area of Montana, the east side of Glacier National Park, and in the Boise and Shoshone National forests. Additionally we identified a Eurasian lynx in the Ashley National Forest.

Non-Invasive Genetic Sampling for Forest Carnivore Population Status at an Ecosystem Scale [TWS]

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We censused populations of grizzly bears and black bears during 1998-2000 on a 8,100-sq. km. study area in northwestern Montana by collecting hair from hair snares and scats from trap grids and survey routes and identifying individuals through DNA analysis. Of the 212 different individual grizzly bears identified during 1998; 121 were detected at systematically placed baited hair traps, 56 from unbaited rub trees, and 35 were detected via both types of samples. Species and gender ratios differed significantly between the three sampling methods. Surveys conducted the first half of the field season yielded larger numbers of samples than later surveys and detected most individuals identified during the entire May – October season. Population point estimates made using a variety of models and combinations of data sets ranged from 343–400 grizzly bears. The 95 percent confidence interval ranged from 263–575 or 33–71 bears per 1000 sq. km. We describe a new noninvasive approach for monitoring bear population trend based on systematic surveys for animal hair and feces. Field collection and population estimation methods, as well as potential sources of genotyping errors and recommendations for minimizing them are described.

Wolf Predation and Predator-Prey Dynamics in the Firehole-Gibbon-Madison Drainages of Yellowstone National Park, WY [TWS]

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Much controversy surrounds the reintroduction of the gray wolf (*Canis lupus*) to Yellowstone National Park (YNP), Wyoming, where a major concern is the effect of this top-trophic level predator on the ungulate populations. The objectives of this study were to examine the prey selection and predation rates of wolves on the ungulate populations in the Madison, Firehole, and Gibbon drainages of Yellowstone National Park. Quantitative data were acquired during the 1998-2000 winters in the Madison-Firehole-Gibbon drainages. The Nez Perce pack, ground-tracked as 2, 7, and 13 wolves in the three successive winters, established the area as an important part of their winter territory. The ungulate prey base in the study area consists of approximately 650 elk and 900 bison throughout the winters. Necropsies were preformed on wolf kills to ascertain the species, age, sex, and condition of the prey to study prey vulnerability and wolf prey selection. In the 3 years of the study, 101 definite and 29 probable wolf kills were located and necropsied, including 70 elk calves, 34 cow elk, 9 bull elk, 1 unknown adult elk, 13 bison calves, 1 cow bison, and 1 unknown bison. Prey switching was evident, differing between the years of the study. The data collected will be used to help predict impacts of wolf predation on the prey populations.

International Review of Wolf Capture, Handling, and Transport – A New Project in Place ^TWS^

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As wolf populations expand in North America and on other continents, an increasing number of wolves are captured for research and management. And as wolves in the United States are delisted, management will be transferred to other agencies along with the need to transfer our knowledge of practical, humane, and successful field techniques. Yet currently, there are no standards in wolf capture and handling and no single source of information contrasting and comparing methods necessary for defining standards. Wildlife Veterinary Resources, Inc. (WVR) is compiling an international review of wolf capture, handling, and transport. WVR, a tax-exempt organization dedicated to building upon our professional experiences, is developing funding, clerical support, and editors to help wolf professionals compile their growing published and unpublished knowledge. The goal for this comprehensive review is to assemble detailed information from as many qualified wolf professionals as possible in a format acknowledging their contributions. Databases will include: 1) published literature, 2) unpublished information, 3) equipment with company information, and 4) contact information of wolf professionals to facilitate networking. This project is the first comprehensive international review for any wildlife species and will serve as a model for other wildlife. A strategy team of wolf professionals will consult on the review process and address pertinent questions and concerns. Wolf professionals are invited to contribute.

Status of Gray Wolf Restoration in Montana, Idaho, and Wyoming ^TWS^

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Gray wolf (*Canis lupus*) populations were eliminated from Montana, Idaho, and Wyoming, as well as adjacent southwestern Canada by the 1930s. After human-caused mortality of wolves in southwestern Canada began to be regulated in the 1960s, populations began expanding southward. Dispersing individuals occasionally reached the northern Rocky Mountains of the United States, but lacked legal protection there until 1974, after passage of the Endangered Species Act (ESA) of 1973. In 1986 wolves from Canada successfully raised a litter of pups in Glacier National Park, Montana, and a small population was soon established. The Recovery Plan for the wolf in the northern Rockies of the United States identified northwestern Montana, central Idaho, and the Greater Yellowstone Area (GYA) as recovery areas and established a biological goal of at least 30 breeding pairs of wolves throughout these 3 areas for 3 successive years. In 1995 and 1996 wolves from western Canada were reintroduced to remote public lands in central Idaho and Yellowstone National Park. Those wolves were designated as nonessential experimental populations to increase management flexibility and address local and state concerns. The Service proposed to reclassify endangered wolves in northwestern Montana to threatened status and manage them similarly to the wolves in the experimental population areas. That proposal should be finalized by July 2001. Wolf restoration is rapidly occurring in Montana, Idaho, and Wyoming and there were at least 25 breeding pairs in December 2000. Currently there are about 61 wolves in northwestern Montana, 185 wolves in central Idaho, and 164 wolves in the GYA. Dispersal of wolves between Canada, Montana and Idaho has been documented but only 1 wolf has successfully traveled to or from the Yellowstone area. Occasional lone wolves are expected to disperse into adjacent states but pack establishment outside of Montana, Idaho, and Wyoming is probably not imminent. At the current rate of population growth the gray wolf in the northwestern U.S. should be recovered and, depending on the status of state and tribal wolf management plans, could be proposed to be removed from the ESA within 3-5 years. Wolf restoration has proceeded more quickly and with more benefits, such as public viewing than predicted. Problems, including confirmed livestock depredations, have been lower than estimated. Wolves have restored an important ecological process to several large wild areas in the northern Rocky Mountains of the U.S. The program has been widely publicized and is generally viewed as very successful.

Wolf Management in Montana TWS

Chase Hibbard, Chair
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The wolf is listed under the federal Endangered Species Act of 1973 and Montana's Nongame and Endangered Species Conservation Act of 1973. Among the federal requirements for delisting, the states of Montana, Idaho, and Wyoming must have management plans in place to ensure that the recovered wolf population will remain secure within the northern Rocky Mountain Recovery Area. The Montana Wolf Management Advisory Council was appointed by an Executive Order signed by former Governor Racicot. The Council is charged to advise Montana Fish Wildlife and Parks as it prepares a management plan for wolves once they are delisted. The Council is comprised of 12 members from around the state who represent a variety of interests including tribal, agriculture, hunting, and wildlife conservation. Using an "interest-based" process, the Council specifically deliberated issues related to: defense of life and human safety, livestock depredation, compensation, management of prey populations, and wolf conservation and management. By consensus, the Council adopted 26 Guiding Principles which will serve as the foundation for Montana's Wolf Management Plan. The Council recognizes the wolf as a native species and a valuable part of our wildlife heritage. Integrating and sustaining wolves within the complex biological, social, economic, and political landscape of Montana presents many challenges and opportunities that all Montanans share. The State of Montana must ensure human safety, safeguard the livestock industry, maintain viable wildlife populations, and uphold the support of people with diverse public interests. The presentation will summarize the Council's Report to the Governor.

The Role of Natural Resource Professio als i Outreach Education [TWS]

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Most resource management professionals have a vocation rather than a job. A vocation is a rare and precious possession, but it obligates natural resource professionals to greater expectations. Our vocation demands from us that our actions truly benefit wildlife, rangelands, and other natural resources. Simply punching the clock is not enough. Our actions are more effective when we reach beyond our ranks and communicate with others who share an interest in natural resources. The size and diversity of this audience is great and ever-expanding, including youth, environmental and conservation groups, sportsmen, commodity groups, policy makers, and other concerned citizens. Natural resource professionals need to seize every opportunity to make a positive difference and relish the pleasure of talking about our favorite subject with other people. We need to share our passion for our vocation and the natural resources we love. Enthusiasm is infectious and encourages people to listen to our message. However, effective communication ultimately depends on honesty and credibility. We must try not to proselytize our audience, but instead provide people with factual information. Empowered with this knowledge, our audiences may reach the same conclusions that we have, and may eventually share our personal values and opinions about natural resources. It is imperative, however, that we recognize the values and opinions of others and try our best to understand them. This approach enables natural resource professionals to experience one of the miracles of teaching, when after the session, not only the audience knows more, but so does the speaker.

Making Your Presentations Easy and Effective [TWS]

Cindy Staszak
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How many of us dread that inevitable phone call that starts off something like this: "Can you come and give a presentation to my class of 100 7th graders tomorrow?" Do those words strike fear in your heart? You need not feel out there all alone. Help is just a phone call away. Biologists and specialists are often called upon to provide presentations for school groups and service organizations. Your presentation can be made much easier and more effective with a variety of tools, tips and props at your disposal. This presentation will discuss and show examples of these tools and provide resource lists for your use.

The Wildlife Investigator Series [TWS]

William I. Dean
USDI Bureau of Land Management, Butte Field Office, Butte, MT 59702

John J. Van Niel
State University of New York, Finger Lakes Community College, Lincoln Hill Campus, Canandaigua, NY 14424

The Bureau of Land Management and Finger Lakes Community College have developed wildlife educational programs for use by wildlife biologists and this presentation is part of the peer review process. The Wildlife Investigator Series includes three wildlife education programs: Wildlife Biologists - a day in the field; Wildlife Trees, Snags and Logs; and Skulls, Antlers and Horns. They are prepared for use with primary, middle, and high school students. Each program has a base lesson from which all lessons are extended. Each Program will include: photographic slides with narration; "hints for presenters"; activities; handouts; and CDROM with power point presentation. Lessons are designed to last between 25 and 45 minutes, and can be customized by presenters to meet her/his needs. Students will be given tasks to encourage critical thinking and applied knowledge. These programs meet Montana State Board of Education Standards. This project will provide positive exposure for resource management agencies, quality educational experiences for persons of all ages, a public more informed about and more appreciative of wildlife resources, and increased public understanding of the BLM's mission and goals. These programs will be presented in a BLM Technical Note publication including a CD.

Building Partnerships for Enhancing Montana's Madison and Missouri River Corridor [TWS]

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PPL Montana and state and federal resource agencies have recently signed a 10 year Memorandum of Understanding (MOU) which provides a consultation framework and funding mechanism for implementation of wildlife, fisheries, water quality, and habitat protection, mitigation, and enhancement measures for the 500 mile Madison and Missouri River corridor as part of PPL Montana's Project 2188 FERC License. The MOU combines efficiencies and innovation in the operation of competitive corporate business with public agency and NGO incentives for adaptive resource management. The MOU collaborative, in the first year of implementation, has identified significant cost-share partnerships exceeding $50 million over the next 10 years between PPL Montana, resource agencies, and NGO's for various fisheries and wildlife projects including wetland, riparian, and associated upland restoration projects within the river corridor.

Streamflow and Cottonwood Recruitment [TWS]

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Cottonwood stands along the Wild and Scenic reach of the Missouri River in Montana are sparse and discontinuous. Because the recreational and wildlife values of these stands are high, there are concerns about how flow alteration and cattle grazing may be limiting reproduction. A retrospective study using tree excavation and dendrochronology established that current trees were disproportionately established in flood years. Results from an ongoing monitoring study suggest that (a) in most years large numbers of new seeds germinate in the bare, moist zone between the flow lines of the spring peak and fall minimum; (b) seedling mortality in subsequent years is extremely high because of grazing, flood damage, and winter ice scour; and (c) successful recruitment is most likely when infrequent high flows have positioned seedlings high on the bank, where local channel movement occurs, and when grazing intensity is low.

Protecting Riparian and Wetland Habitats in the Madison and Missouri Valleys as part of the Montana Wetlands Legacy [TWS]

Tom Hinz
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Although agencies and organizations across Montana have been in the business of protecting wetlands, riparian areas, and uplands for several decades, many of these programs have been operated independently or in limited partnerships. With federal funds, foundation grants, and other state, regional, national and international funding sources becoming increasingly more available, a fully-integrated collaborative approach to land and water protection makes most sense for Montana. In the area of wetland and riparian protection, the Montana Wetlands Legacy is such an integrated partnership. Formed in May, 2000, the Legacy partnership includes representatives of every major on-the-ground habitat protection organization in the state. In 2000, the Legacy adopted a short-term goal of protecting 100,000 acres of wetlands, riparian areas, and associated uplands throughout Montana by 2005. The issuance of the FERC order to PPL-MT for operation of its nine major dams on the Madison and Missouri Rivers over the next forty years provided a unique opportunity for conservation partners, including the Montana Wetlands Legacy, to partner with PPL-MT's sizeable and long term source of private funds for riparian and wetland protection. The Montana Wetlands Legacy partners have begun the process of matching PPL-MT funds with state and federal program dollars, as well as those from private conservation groups, to purchase conservation easements, manage grazing along streams, and to gather information on wildlife populations, distribution, trend and abundance in the Missouri-Madison area. Ultimately, through the Montana Wetlands Legacy and related partner efforts, we hope to protect the best of these important wetland and riparian habitats.

ASSESSING WINTER RECREATION EFFECTS ON STRESS HORMONE LEVELS OF ELK AND BISON IN YELLOWSTONE NATIONAL PARK TWS

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The effect of winter recreation on animal populations is widely debated, particularly since a recent decision by the US Department of the Interior to ban snowmobiles from National Parks. Immunoassays of fecal glucocorticoid levels provide a noninvasive method of measuring physiological stress responses of wildlife to disturbances. Here, we relate snowmobile activity to glucocorticoid levels of an elk (*Cervus elaphus*), and bison (*Bison bison*) population in Yellowstone National Park. In preliminary results for elk, day-to-day variation in fecal glucocorticoid levels tracked variation in the number of snowmobiles, after controlling for effects of weather and age. Glucocorticoid concentrations were higher in response to snowmobiles than in response to wheeled vehicles, after controlling for effects of weather, age and number of vehicles. Results for bison are pending. Despite these stress responses, there is no evidence that current levels of snowmobile activity are affecting population dynamics for either species.

ADULT FEMALE WHITE-TAILED DEER IN MONTANE ENVIRONMENTS: WHAT ARE WE MANAGING AND WHAT ARE WE COUNTING? TWS

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Despite their popularity as a big game animal and prevalence in the hunter bag, comparatively little is known about white-tailed deer response to various hunter harvest strategies in montane environments. Prior to developing an adaptive management protocol for white-tailed deer, it is important to evaluate the regulation packages and validate their anticipated outcomes. In addition, it is important to validate a monitoring protocol. One objective of the Northwest Montana Deer Research Project is to investigate the effects of various regulation types and variable harvest opportunities for antlerless deer. Telemetry was used to determine adult female harvest rates in each of two hunting districts (HD) under various regulation packages and variable antlerless harvest opportunity through time. Whereas the regulations pertaining to the general deer "A" license were consistent for each district, they did change through the 1988-2000 period of study. Antlerless harvest opportunity also changed during the period, though the changes were systematically adopted in only one HD during the hunting seasons 1991-1996, while the other HD served as a control. This permitted comparisons through space and time. Biologists frequently utilize results from the annual telephone harvest survey to monitor trends in total deer harvest for various age and sex categories. Estimates for antlerless harvest (number of deer harvested) were compared to estimated harvest rates of telemetered does. Abiotic factors were also considered. The presentation will summarize preliminary results.

Adaptive Harvest Management Of Mule Deer In Montana [TWS]

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A decline in mule deer populations in the mid-1990's provided impetus for innovation in mule deer harvest management. The FWP Commission officially adopted the Adaptive Harvest Management (AHM) process in 1998. Recognizing that there is much we do not understand about the dynamics of mule deer populations sets AHM apart from traditional forms of management. Strong differences of opinion concerning the effects of hunting regulations on population trends result from uncertainty about the effects of hunter harvest. A redesign of the entire management process improves identification and consideration of these uncertainties to reveal new knowledge about the resource. Four basic components are linked in this process: 1. Population goals and objectives are specific to differences in population characteristics among five important environments. Objectives for each environment define levels of fluctuation more acceptable to landowners and hunters. 2. Population monitoring has been reorganized to increase quality and consistency of data on population size and composition using standardized methods. Monitoring includes two levels of aerial survey intensity: trend areas and census areas. The former are flown twice per year (post-hunting season and spring) and the latter 4 times per year (post-hunting season and 3 times in spring). Post-hunt surveys occur between December 1 and January 15 and spring surveys between March 15 and April 30. Trend areas provide data on status of local populations at 67 sites across land ownerships and land-uses. Replicate surveys during spring on census areas provide detailed data on size and composition of 13 important populations across the major environments. Monitoring data define population status in relation to objectives and connect together the other components of the AHM process. 3. Hunting Regulations in a three-part package (restrictive, standard, liberal) provide an array of harvest rates for populations in each environment. Recommendations to change regulations are triggered by a priori thresholds of population size and composition. 4. Computer Models of prairie and mountain mule deer populations have been constructed using STELLA modeling software. Data on population size and composition from the 13 census areas are integrated with environmental data and harvest regulations to predict population status one year into the future. Feedback between modeling and monitoring allow comparison of model predictions to observed population data. This process improves detection of significant changes in population status and provides more timely response. Annual iteration of the AHM process brings harvest management closer to an organized experiment, rather than simply an ongoing experience.

Estimating Total Human-Caused Mortality from Reported Mortality Using Data from Radio-Instrumented Grizzly Bears [TWS]

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Mark Haroldson and Charles C. Schwartz
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Tracking mortality of the Yellowstone grizzly bear (*Ursus arctos horribilis*) is an essential item of the recovery process. Agency removal of problem bears is known. Additionally, the public reports an unknown proportion of bears they kill. Estimating the number of non-agency human-caused mortalities is a necessary element that must be factored into the tally of total annual mortality. Here, we describe a method of estimating non-agency human-caused grizzly bear deaths from records of reported human-caused bear mortalities. We used a hierarchical Bayesian model, with an assumed noninformative prior distribution for the number of deaths. Information from reporting rates of deaths in radio-instrumented bears from 1984 to 1999 is used to develop 3 beta prior distributions on the probability that the public will report a death. Different prior results from different assumptions about the fates of unexplained/unresolved loss of signal incidents. We apply the method to reported human-caused mortalities in running 3-year time periods starting in 1993 through 2000. Two distinct data sets are analyzed: one with possible deaths included and one with possible deaths excluded. We believe results from the described method can be combined with agency removals to produce defensible estimates of total mortality over relevant time periods and incorporate uncertainty when evaluating mortality limits established for the Yellowstone grizzly bear population. Assumptions and limitations of this procedure are discussed.

The Effect of Environmental Variability on Grizzly Bear Habitat Use: A Work in Progress [TWS]

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Robert Garrott
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The grizzly bear (*Ursus arctos*), with mean adult home range sizes ranging from just under 500 square kilometers to over 800 square kilometers, is a wide-ranging omnivorous carnivore whose habitat requirements are challenged daily by increasing habitat fragmentation. Many of the measurable parameters that characterize habitat use by grizzly bears are influenced by the quality, quantity and distribution of available resources at many temporal and spatial scales. The availability of these resources is further complicated by the annual and inter-annual variability in human land use patterns and a suite of climatic variables. In order to gain ecological insight regarding how the grizzly bear uses the

landscape and what effect human land use changes have on that landscape, it is important to determine the daily movements of grizzly bears. Delineating daily movements and determining the location of resources that act as attractants vs. resources that act as deterrents is an objective of this project. The global positioning system (GPS) technology provides scientists with location information having a high degree of certainty and at user defined intervals. This paper will present the initial findings of a multi year study, based in the Greater Yellowstone Ecosystem, using the technologies of GPS, Geographic Information Systems and remotely sensed data to assess the effects of resource management strategies and land use practices on grizzly bear habitat selection. To date 26 grizzly bears have been instrumented with GPS collars. Based on data from retrieved this project has been able to illustrate that there are indeed patterns of use delineated using the GPS technology that were not captured using traditional radio telemetry methods. Grizzly bear home ranges delineated using this technology are much more discrete showing areas of concentrated use. These results appear to have promise in providing new ecological insights on grizzly habitat selection.

Ecosystem Scale Linkage Identification and Implementation for Grizzly Bears and Other Rocky Mountain Carnivores [TWS]

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The fragmentation of carnivore habitat in the Rocky Mountains on both sides of the U.S.-Canada border is an ongoing threat to the survival and recovery of these populations. Human developments are the cause of this fragmentation. Major developments causing fragmentation include private land conversion into homesites and highway construction and improvement. If carnivores such as grizzly bears (*Ursus arctos horribilis*), wolves, (*Canis lupus*), wolverines (*Gulo gulo*), lynx (*Lynx lynx)*, and fishers (*Martes pennanti*) are to survive and recover to healthy population levels in the Rocky Mountains, the issue of fragmentation must be addressed in a proactive and effective manner. Addressing the issues of habitat fragmentation for carnivores requires an organized effort. We have been involved in the development of a linkage zone identification effort as part of the grizzly bear recovery program. As part of this effort, we have developed a linkage zone prediction model that was used to identify the linkage areas within and between the major blocks of public lands in the Rocky Mountains of Montana and Idaho.There is a need for careful management of activities to allow carnivores the continued opportunity to move across lands in linkage areas. We have proposed general management considerations on public lands to facilitate movement across such areas by carnivores. Lands that offer the greatest threat to movement and occupancy by carnivores are private lands where development and subdivision can have serious impacts on wildlife and the statutory authority of the government under the Endangered Species Act is minimal. Management efforts must be undertaken on these lands with the cooperation and coordination of the owners. Suggested management activities on private lands to maintain linkage opportunities for carnivores were discusssed. Highways are a major factor in habitat and population fragmentation. As existing highways are improved for safety and increased traffic, they become increasingly difficult for wildlife to cross. Designing highways to allow wildlife crossing will also improve human safety by decreasing vehicle-wildlife collisions saving human and animal lives. Suggestions for maintaining and enhancing crossing of highways by carnivores were discussed. The future cumulative levels

of human development on private lands combined with accelerating highway improvements will result in complete fragmentation of many carnivore populations unless management of linkage zones is initiated immediately. It will be necessary for management efforts to simultaneously address the linkage needs on public and private lands and on the highways that traverse these areas. It will be much easier to maintain opportunities for population linkage than to recreate them, so the time for action is now.

Do Highways Form Barriers to Small Mammal Movement and Gene Flow? TWS

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Highways can adversely affect wildlife populations by increasing mortality due to vehicular collisions and by discouraging crossing attempts, leading to decreased connectivity among populations. We are investigating these issues using small mammals as a model system. First, we are using mark-recapture analyses to compare movement adjacent to highways to movement across highways for small mammals in forested areas in western Montana. Second, we are determining rates of gene flow across highways and the degree of genetic differentiation that may have occurred in red-backed voles (*Clethrionomys gapperi*), deer mice (*Peromyscus maniculatus*), and vagrant shrews (*Sorex vagrans*). In our first field season, we recorded 1378 captures of 624 individuals of 10 species. Preliminary results indicate that more individuals moved between grids on the same side of the highway than between grids separated by the highway: 39 movements adjacent to the highway versus 16 movements across the highway. These 55 movements were completed by 40 individuals, 75 percent of which were male. Deer mice and chipmunks appeared to be more successful at crossing highways than red-backed voles. Only one vole (who crossed twice) was ever captured on both sides of the highway, compared to seven movements of five individuals adjacent to the highway. Our goal is to assess the barrier effect of highways of different widths on various species of small mammals, so that these negative impacts can be identified and mitigated in the future.

Mitigating the Effects of Kerr Dam on Wildlife Within the Flathead Indian Reservation TWS

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Kerr dam was initially licensed in the 1930s and began controlling the outflow of Flathead Lake in 1938. A new license was applied for and granted in 1985 contingent on mitigation measures to be determined. Impact studies, damage assessments and an initial mitigation plan were completed in 1990. The Federal Energy Regulation Commission approved a partial settlement in 1998 and a final settlement in January 2001. Documented losses include 1792 acres of wetland and riparian habitats along the shores of Flathead Lake

and 985 acres of shoreline habitat along the lower Flathead River lost because of altered lake and river hydrographs, and 624 acres of riparian habitat along the lower Flathead River lost because of flood control. Half of the lost riparian acres (312) were attributable to operations at Hungry Horse Dam on the South Fork of the Flathead River and will not be mitigated under the Kerr settlement. A Fish and Wildlife Implementation Strategy was developed that covers program goals, specific mitigation activities, threatened and endangered species, monitoring methods, and an adaptive management strategy. A Habitat Acquisition and Restoration Plan was developed that outlines acquisition priority areas on the Flathead Reservation, criteria to prioritize individual parcels, an accounting system to measure habitat crediting and a structure for restoration and management activities. This paper will give an overview of the Confederated Salish and Kootenai Tribe's acquisition plans, management goals, restoration efforts and other activities planned as part of this mitigation effort.

Sage Grouse Status and Harvest Opportunities in Northeastern Montana [TWS]

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A population of sage grouse (*Centrocercus urophasianus*) in Valley County, Montana were first investigated 45 years ago. Three leks have been surveyed over most of this time period. Since 1989, managers have intensively surveyed a 36,000 ha block area within the county. Information from this block area has become the tool for local managers in assessing sage grouse trends. In past two years sage grouse leks in the entire southern half of the county have been searched for and surveyed. Numbers of male sage grouse observed in 2000 numbered over 1300 in Valley County. By using the relationship between the block area, total counts over the past two years and fall wing harvest collections, managers were able to estimate spring and fall populations since 1989. Yearly estimates from the statewide harvest surveys have found the harvest in Valley County to vary from just over 250 to over 1800 sage grouse since 1989. During this period, hunting seasons varied from 62 to 107 days in length, had daily limits between 2 and 4 birds and possession limits between 6 and 16 birds. Comparisons between the population and harvest estimates reveal a population that is independent of the liberal hunting opportunities offered.

Montana-Wide Burrowing Owl Surveys; A Synthesis of First and Second Year Efforts, 1999-2000 [TWS]

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In 1999, we initiated the first statewide survey efforts for Burrowing Owls (*Athene cunicularia*) across Montana with a stratified random inventory of 204 black-tailed prairie

dog (*Cynomys ludovicianus*) colonies yielding an estimate of 644 + 114 owl pairs inhabiting Montana prairie dog colonies. During 2000, 28 cooperators surveyed 187 prairie dog colonies estimating that 727 + 168 Burrowing Owl pairs inhabited Montana colonies. Seven hundred seventeen owls were observed including 134 pairs. Of 1353 colonies within the working dataset comprising approximately 67200 acres (27206 ha), we surveyed 15.1 and 13.8 percent by number and 15.0 and 14.3 percent by area (10079 acres, 4081 ha; 9602 acres, 3887 ha) during 1999 and 2000, respectively. Seventy-nine colonies contained owls yielding an occupancy rate slightly higher in 2000 than during 1999 (42.25 vs. 38.24%, respectively). Although surveyors appeared to observe greater numbers of owls during year 2000 (mean + SE; 3.59 + 0.56 vs. 2.29 + 0.30) the difference was not significant. There was a small tendency to observe greater numbers of adult females, young, and adult males during 2000 but these trends were negligible when adjustments for multiple comparisons were made. No significant difference between years in number of owl pairs per surveyed colony was detected. Analysis of bellweather and random colonies is ongoing for determining trends.

A Comparison of Sin Nombre Virus Prevalence in Peridomestic Versus Sylvan Populations of Deer Mice [TWS]

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Most cases of hantavirus pulmonary syndrome (HPS) are likely acquired in peridomestic settings, including human dwellings, out-buildings, corrals and ranch yards, yet studies of the ecology and infection dynamics in the reservoir host, the deer mouse (*Peromyscus maniculatus*) have focused on sylvan populations. We describe a 2.5-year study of hantavirus infection in rodents associated with peridomestic habitats at three study sites in west-central Montana. Antibodies reactive with Sin Nombre virus (SNV) were found in 5 species. Overall SNV antibody prevalence was highest among deer mice (25% of individuals tested). Characteristics of these peridomestic populations of deer mice were then compared with those of sylvan populations from 6 different sites in western and central Montana. In both types of populations, the antibody-positive component of the deer mouse population consisted of a higher proportion of adults and males. However overall SNV antibody prevalence and average monthly prevalence was significantly higher in the peridomestic populations. The higher SNV antibody prevalence in peridomestic compared with sylvan settings may be related to behavioral differences and/or potentially longer survival of the virus deposited inside buildings. Peridomestic settings presented higher concentrations of virus and may present a higher risk of human infection than do sylvan settings.

Landscape Effects on Duck Nesting Success in the Missouri Coteau Region of North Dakota: Preliminary Analyses [TWS]

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Understanding relationships between landscape characteristics and demographic parameters is a critical component of maintaining viable populations in human altered ecosystems. Thus, this information is paramount for natural resource managers charged with implementing successful conservation programs. We are currently investigating nesting success rates for dabbling ducks across a gradient of landscape types in the Missouri Coteau region of North Dakota. A variety of functional forms of the relationship between nesting success and the amount of grassland cover in the landscape are possible. Each form would result in dramatically different management implications, if operating. We used simulation modeling to help guide the design of this study to maximize our ability to discern among the various forms of this relationship. The appropriate scale at which to measure the landscape characteristics was also of interest in this work. This study was designed to examine landscape characteristics at 4 and 36 square mile spatial scales. Eighteen study sites were selected using satellite imagery to obtain a range of grassland levels at both the 4 and 36 square mile scale. As a result, study sites encompass the full gamut of landscape types from those dominated by agricultural fields to sites entirely comprised of native pasture. During the first field season, 2,200 duck nests were located using chain drag techniques and monitored for success along with over 150 nests of other grassland nesting birds. Preliminary estimates of nesting success from this first field season will be presented along with initial plots of the grassland-nesting success relationship.

Suitability of Montana Wildlands for Bison Reintroduction [TWS]

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Montana contains several large tracts of wildlands that would be suitable for bison (*Bison bison*) reintroduction. Four of these sites were selected for further consideration and were found to range in size from 187,458 acres to 895,503 acres. Each of the sites contained greater than 90 percent Federal and state ownership, and were largely uninhabited. Two sites would support resident bison herds in prairie/river breaks habitat and two sites would support migratory bison herds in mountain/foothills habitat. Bison could be obtained from Federal and state-owned bison herds that utilize similar habitats as the proposed reintroduction areas. All reintroduced animals would come from herds free of regulatory diseases, and would be certified as healthy by a qualified veterinarian. Reintroduction would begin with a soft release of five yearling bison at each site to establish a herd range within a specific area. Once established, additional bison could be added to the herds as necessary. Principles of modern conservation biology would be used to maintain genetic diversity

within and between herds through periodic translocations and introductions. Bison herds would be allowed to expand to 50 adults at which point they would be managed through regulated public hunting. Wild bison are classified as a game animal in Montana and would be held in the public trust. Montana Fish, Wildlife and Parks has management authority over disease-free wild bison and existing statutes are suitable for management of wild bison. Small bison herds are expected to be extremely cohesive, utilize habitats differently than cattle, distribute their range utilization over a broad area, and to be compatible with existing land uses and other wild ungulates.

Coal Bed Methane – Too Many Unanswered Questions [TWS]

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Issues affecting people in Rosebud and Powder River Counties are felt by people in Missoula, Great Falls, Bozeman and Helena. Diminished water quality in the Tongue and Powder rivers affect all Montanans. Coal bed methane (CBM) is being pumped from coal seams in southeast Montana. High natural gas prices, cheaper drilling technology, and a need for cleaner-burning fuels has spurred rapid growth of the CBM industry. Unfortunately, there is no scientific data showing that CBM development is environmentally advisable. Why would the agricultural community be up in arms against what appears to be a benign type of development that could be a boon to local economies and create more apparent water in a semi-arid region? Montana farmers and ranchers and others who are familiar with this country are afraid because there are too many unanswered questions and too many obvious negative impacts associated with CBM development. Redstone's project on the CX Ranch at Decker presently operates 143 wells, with more to come when the permitting process allows them. According to a briefing paper prepared by DEQ, "Every minute, each well produces about 20 gallons of salty, sodium-rich water that may contain toxic substances (including arsenic and barium at concentrations exceeding water quality standards). At this rate, 30,000 wells could potentially discharge enough of this brackish water to roughly double the flow of the streams in the Powder River Basin CBM region during the irrigation season." Hundreds of active wells are presently discharging polluted water directly to Tongue and Powder River and their tributaries. Extracting methane involves pumping millions of gallons of water out of coal seams onto the land, water that cannot be used to irrigate haylands or gardens because of the salts and other dissolved solids – water that kills the vegetation and the soil. According to DEQ, other potential impacts include dewatering of local and regional aquifers, decreased natural surface water availability in some areas, increased brackish surface flow in discharge areas, miles and acres of roads and surface facilities, erosion, sedimentation, and increase of sodium and other soluble pollutants to streams that will have substantial impacts on native fish populations. There may also be ground water reduction that dries up stock water, loss of natural artesian well pressure, increased saline seep, increased air and noise pollution from compressors, lower water tables, and significant water quality degradation. Prospects of thousands more wells in this country should concern all of us. I fear not only the obvious potential impacts to Montana's surface and ground waters, but to already significantly reduced sage and sharp-tailed grouse populations, nesting neotropical birds and raptors, and impacts to daily and seasonal movements of mule deer and pronghorn, to name a few. Tongue River supports many warm, cool and cold-water gamefish species that will be negatively affected by pollution. These are just a few of the known environmental costs. On the unknown side of the ledger, DEQ admits they don't have a clear understanding of the myriad cumulative negative effects of CBM development, and they willingly admit there are more questions than answers regarding impacts.

Bison and Brucellosis: Integrating Research and Management [TWS]

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Montana Fish, Wildlife and Parks,
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Previous management efforts designed to minimize the risk of transmission of brucellosis from free-ranging bison and preserve Montana's brucellosis free status have been hampered by the lack of specific scientific information. Interim management strategies were conservative and sometimes extreme because of the uncertainty associated with management decisions in the absence of quality risk management data. Early management discussions and even public debates were based on various untested hypothesis and subjective scientific opinions in the absence of specific research data. Answers to basic questions about pathogenesis, epidemiology, and possible treatment/risk management strategies were not available and research to address these topics was not in place. Recent efforts by multiple agencies to examine the pathogenesis and epidemiology were begun in 1995. Additional research into vaccine safety and efficacy were also initiated and are nearing completion. Recent discoveries from these studies include tissue localization of *Brucella abortus* following exposure and active infection, serology-culture relationships, serologic conversion rates, age specific infection rate, manifestations of the disease in bison, shedding of brucellosis in the environment, persistence of brucellosis in the environment, possible mechanisms of transmission, potential vaccines, and vaccine safety in non-target species. Additional research projects are proposed or underway to further define persistence of brucella in the environment, determine disappearance rates of fetuses in the Greater Yellowstone Area, monitor the infectiousness of sero-negative pregnant bison, explore vaccine delivery using biobullet technology and determine if latency of infection occurs in sero-negative calves. The final state-federal bison management plan was approved in December, 2000. The management plan describes an adaptive management strategy that incorporates specific research projects and monitoring to help define parameters to be incorporated into the decision process. Results from recently completed and ongoing research efforts are providing detailed definition to a complex management problem and provide critical information for advanced risk modeling. This presentation describes current progress in brucellosis research and application of these findings to management strategies outlined in the long-term state/federal bison management plan. Much progress has been made in understanding and further defining a complex problem, which provides a significant step toward managing the problem.

Prairie Dog Panel - Perspective of the Conservation Community [TWS]

Minette Johnson
Defenders of Wildlife, 114 West Pine Street, Missoula, MT 59802

Defenders of Wildlife is a national non-profit conservation organization of more than

400,000 members and supporters dedicated to preserving the natural abundance and diversity of wildlife and its habitat. We have been working on prairie wildlife conservation in our northern Rockies regional office for over a decade. In 1995 we commissioned a study to evaluate the status of black-tailed prairie dogs. We were concerned by the apparent declines in the species particularly because the black-tailed prairie dog is a keystone species of the grasslands. It is estimated that 170 species rely at some level on prairie dogs for their survival, including America's rarest land mammal, the black-footed ferret. The 1995 study documented that black-tailed prairie dog acreage had been reduced by 98 percent nationwide since the turn of the century. Similar declines have occurred in Montana, where we now have only 70,000 acres occupied by prairie dogs. Large-scale poisoning campaigns, habitat loss primarily from conversion to agriculture, sylvatic plague, and shooting have all contributed to the shrinkage of their range. Defenders of Wildlife and other conservation organizations are taking numerous steps to improve the plight of black-tailed prairie dogs and to conserve and restore grassland ecosystems in Montana and throughout the Great Plains.

Prairie Dog Panel - Perspective of the Bureau of Land Management [TWS]

Marc Whisler
USDI Bureau of Land Management, P.O. Box 36800, Billings, MT 59108

As a federal agency, the Bureau of Land Management (BLM) has a trust responsibility to ensure that actions authorized on BLM administered lands do not contribute to the need to list any species under the provisions of the Endangered Species Act (ESA). In Montana, both the white-tailed prairie dog (a BLM Sensitive Species) and the black-tailed prairie dog (a Federal candidate species) fall under BLMs Special Status Species management direction. The BLM State Director is responsible for developing and implementing programs for the conservation of Special Status Species. As such, the State Director will coordinate with State and other Federal agencies, various private organizations, and BLM constituents. Pursuant to this direction BLM has been an integral partner of the Montana Prairie Dog Working Group since its inception in 1996. Prior to that the BLM was a primary partner in the Montana Black-footed Ferret Working Group and assisted with the development and publication of the Montana Prairie Dog Management Guidelines (Montana Black-footed Ferret Working Group, 1988). BLM also co-authored The Prairie Dog Ecosystem: Managing for Biological Diversity. BLM must insure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any federal endangered or threatened species. Given the extensive habitat for prairie dogs on BLM administered lands in Montana, the dependence of black-footed ferrets on prairie dogs, and the need for continued recovery efforts for black-footed ferrets, the BLM is an essential partner and cooperator for conservation of prairie ecosystems and their associated species.

Prairie Dog Panel - Perspective of the Fish and Wildlife Service TWS

Lou Hanebury
USDI Fish & Wildlife Service, 2900 4th Avenue North, Room 301, Billings, MT 59101-1228

On February 4, 2000, the U.S. Fish and Wildlife Service published a 12-month Administrative Finding for a petition to list the black-tailed prairie dog. The Service believed, at that time, that sufficient information was currently available to support a decision that listing the black-tailed prairie dog as threatened is warranted, but that a proposed rule was precluded by work on other higher priority species. The U.S. Fish and Wildlife Service is currently re-evaluating the status of the black-tailed prairie dog and will soon publish a Federal Register Summary and Candidate Assessment form. The species may remain on the candidate list and maintain its listing priority number. In our original finding, the Service found that the recent decline of black-tailed prairie dog occupied habitat is due to several factors, the most influential of which is the widespread occurrence of plague, an exotic and completely lethal disease to the species. Plague could have an even more significant impact on the species if it manifests itself in portions of the range unaffected to date. In concert with plague, the loss of suitable habitat, and inadequate regulatory mechanisms may act upon fragmented populations to threaten the continued existence of the species. Although a number of proposals for regulatory change and active conservation have been proposed, few or none of consequence has been achieved. Plague and inadequate regulatory mechanisms remain the primary challenges and it will take active management range wide to adequately address these threats.

Prairie Dog Panel - Perspective of the Agricultural Community TWS

Ken Blunt
HC 84, Box 8180, Malta, MT 59538

History of my personal involvement in prairie dog issues will be described, as well as how local citizens of Phillips County have been involved in the process since the early 1980's. The history of prairie dogs in Phillips County, and historic and present population levels will be described. Contributions and sacrifices of landowners during the past years of involvement with prairie ecosystem issues will be presented, along with a description of impacts to crop and rangeland resources due to high numbers of prairie dogs. The potential effects of the Montana Prairie Dog Conservation Plan on landowners will be addressed.

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